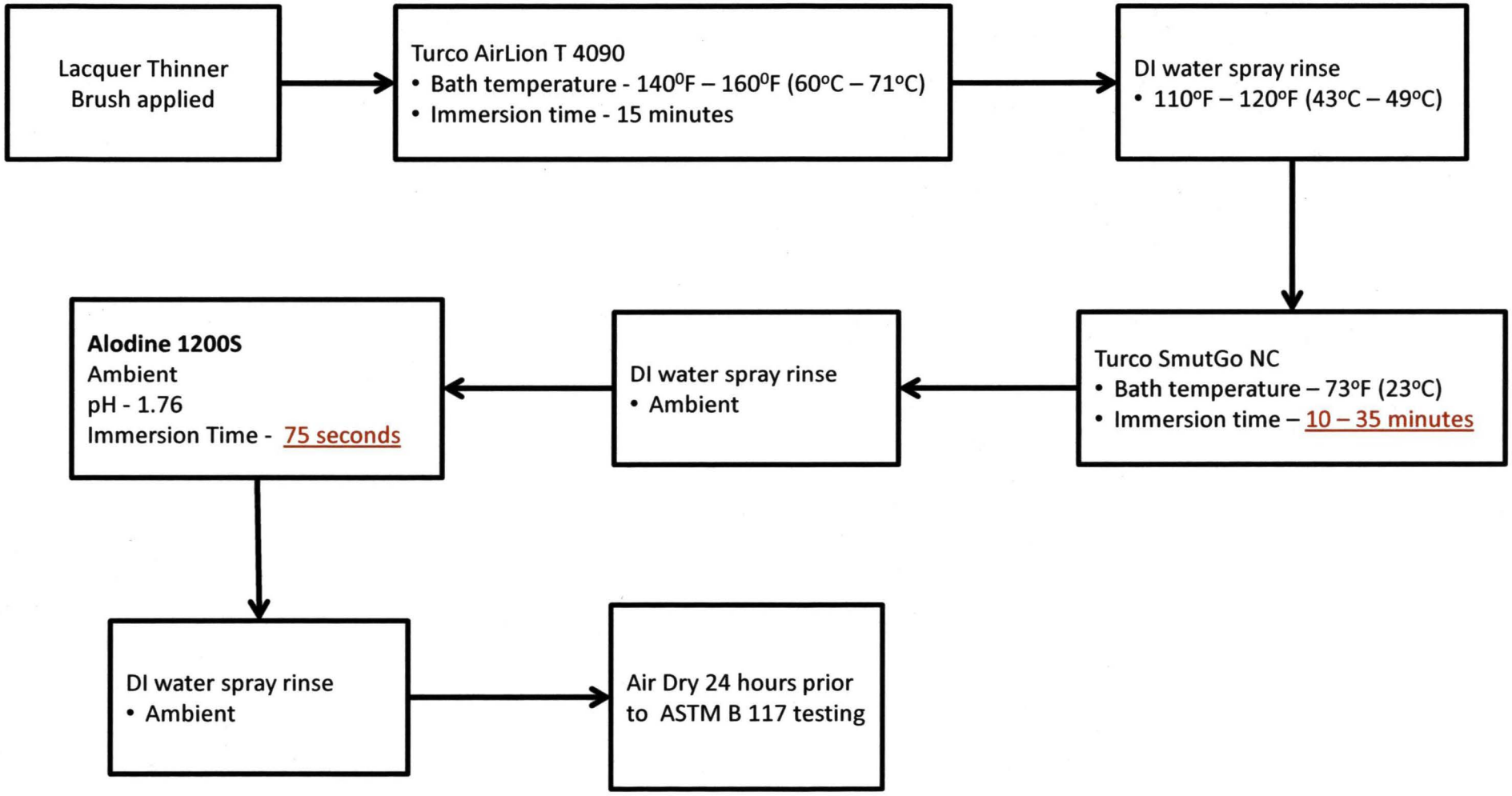
# Hex Chrome Free Coatings for Electronics Overview

# Onsite {KSC} Alodine 1200S Process

## Hex-Chrome Base Line

# Alodine 1200S



| 2024-T3 | ASTM B117 | | | |
|---|---|---|---|---|
| 1:15 min Alodine 1200S | Pit Count 168 Hours | Pit Count 336 Hours | Pit Count 504 Hours | Pit Count 672 Hours |
| 401 (~10 min de-ox) | 0 | 0 | 5+ | N/A |
| 402 (~20 min de-ox) | 0 | 0 | 5+ | N/A |
| 403 (~15 min de-ox) | 2 | 0 | 5+ | N/A |

| 6061-T6 | ASTM B117 | | | |
|---|---|---|---|---|
| 1:15 min Alodine 1200S | Pit Count 168 Hours | Pit Count 336 Hours | Pit Count 504 Hours | Pit Count 672 Hours |
| 601 (~10 min de-ox) | 0 | 0 | 4 | 0 |
| 602 (~15 min de-ox) | 1 | 0 | 4 | 0 |
| 603 (~20 min de-ox) | 0* | 1 | 0 | 3 |
| *one pit starting | | | | |

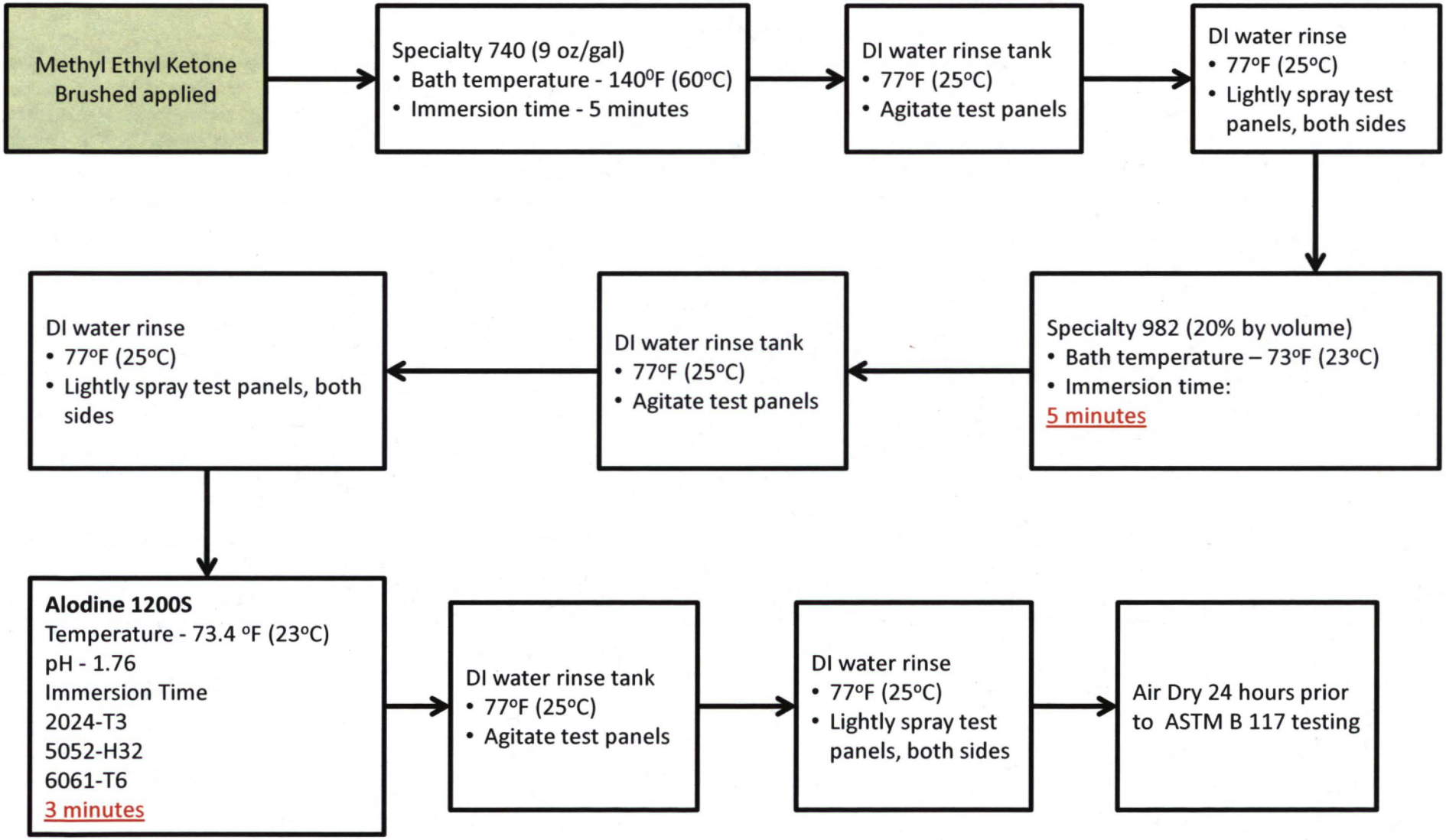
| 7075-T6 | ASTM B117 | | | |
|---|---|---|---|---|
| 1:15 min Alodine 1200S | Pit Count 168 Hours | Pit Count 336 Hours | Pit Count 504 Hours | Pit Count 672 Hours |
| 701 (~30 min de-ox) | 0 | 0 | 0 | 0 |
| 702 (~25 min de-ox) | 1 | 0 | 5* | 7 |
| 703 (~25 min de-ox) | 0 | 0 | 1 | 0 |

# Test Panel Preparation Process Optimization {I}

- Changing initial solvent cleaning process

# Alodine 1200S

KSC Corrosion Lab



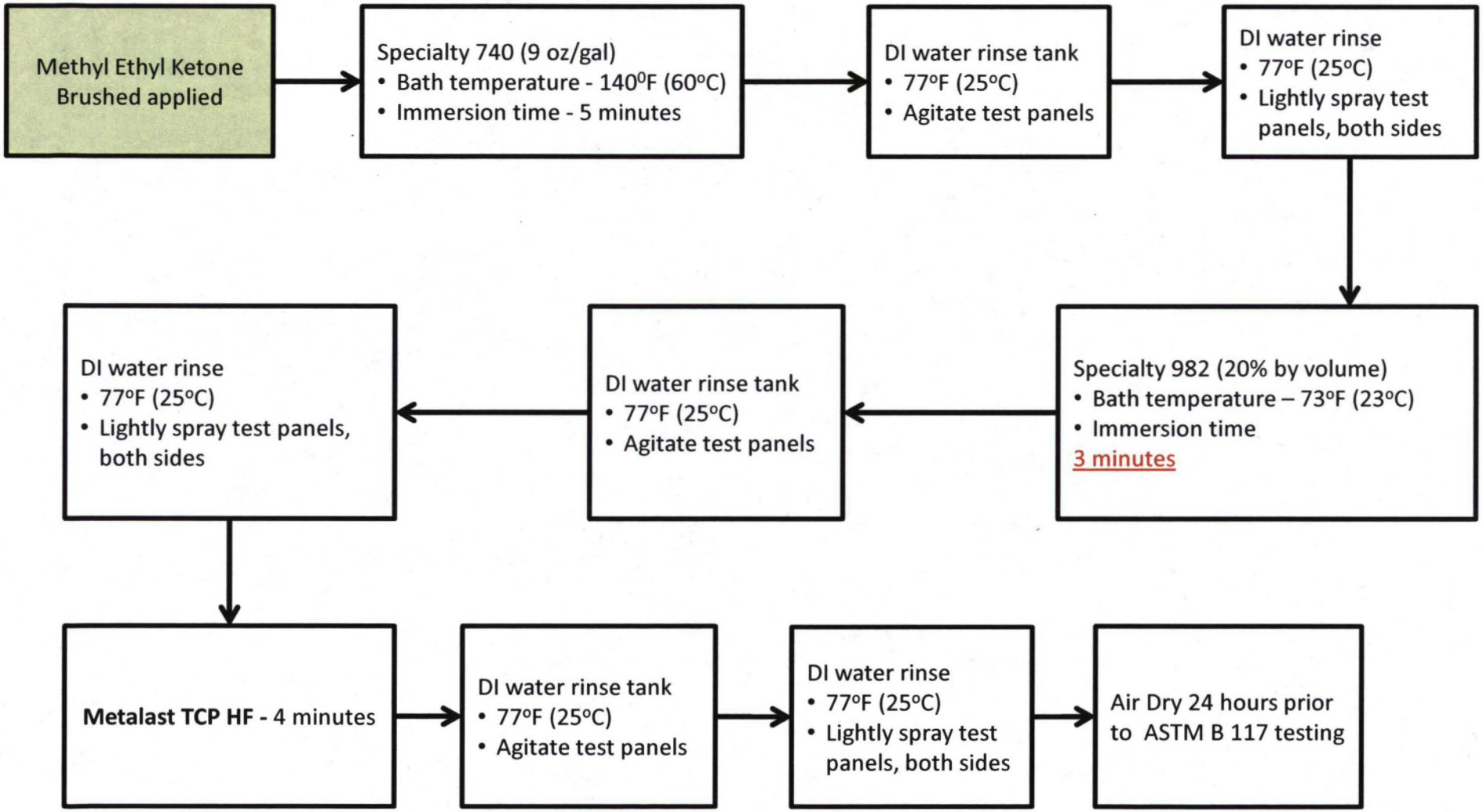
# Alodine 1200S

| 2024-T3 | |
|---|---|
| Specialty 982 Deoxidizer | |
| 5 min de-ox / 3 min Alodine 1200S | ASTM B117 Pit Count 168 Hours |
| Al2024 01 | 5+ |
| Al2024 02 | 5+ |
| Al2024 03 | 5+ |
| Al2024 04 | 5+ |
| Al2024 05 | 5+ |
| Average Coating Weight 72 | |

| 6061-T6 | |
|---|---|
| Specialty 982 Deoxidizer | |
| 5 min de-ox / 3 min Alodine 1200S | ASTM B117 Pit Count 168 Hours |
| Al6061 01 | 5+ |
| Al6061 02 | 5+ |
| Al6061 03 | 5+ |
| Al6061 04 | 5+ |
| Al6061 05 | 5+ |

| 5052-H32 | | | |
|---|---|---|---|
| Specialty 982 Deoxidizer | | | |
| 5 min de-ox / 3 min Alodine 1200S | ASTM B117 | | |
| | Pit Count 168 Hours | Pit Count 336 Hours | Pit Count 504 Hours |
| Al5052 01 | 0 | 0 | 5 |
| Al5052 02 | 0 | 0 | 3 |
| Al5052 03 | 0 | 0 | 1 |
| Al5052 04 | 0 | 0 | 2 |
| Al5052 05 | 0 | 0 | 2 |

# Metalast TCP HF



# Metalast TCP HF

| 2024-T3 | |
|---|---|
| Specialty 982 Deoxidizer | |
| 3 min de-ox / 4 min Metalast | ASTM B117 Pit Count 168 Hours |
| M20 01 | 5 |
| M20 02 | 5+ |
| M20 03 | 5+ |
| M20 04 | 5+ |
| M20 05 | 5+ |
| Test panels allowed to dry prior to pretreatment | |

| 2024-T3 | | |
|---|---|---|
| Specialty 982 Deoxidizer | | |
| 3 min de-ox / 4 min Metalast | ASTM B117 Pit Count 168 Hours | ASTM B117 Pit Count 336 Hours |
| M2024 06 | 0 | 5+ |
| M2024 07 | 1 | 5+ |
| M2024 08 | 5+ | 5+ |
| M2024 09 | 5 | 5+ |
| M2024 10 | 1 | 5+ |

| 5052-H32 | | | |
|---|---|---|---|
| Specialty 982 Deoxidizer | | | |
| 3 min de-ox / 4 min Metalast | ASTM B117 Pit Count 168 Hours | ASTM B117 Pit Count 336 Hours | ASTM B117 Pit Count 504 Hours |
| M50 01 | 0 | 0 | 0 |
| M50 02 | 0 | 0 | 0 |
| M50 03 | 0 | 0 | 0 |
| M50 04 | 0 | 0 | 0 |
| M50 05 | 0 | 0 | 0 |

| 6061-T6 | | | |
|---|---|---|---|
| Specialty 982 Deoxidizer | | | |
| 3 min de-ox / 4 min Metalast | ASTM B117 Pit Count 168 Hours | Pit Count 336 Hours | Pit Count 504 Hours |
| M60 01 | 0 | 0 | 0 |
| M60 02 | 0 | 0 | 0 |
| M60 03 | 0 | 0 | 0 |
| M60 04 | 0 | 0 | 0 |
| M60 05 | 0 | 0 | 0 |

# Metalast TCP HF

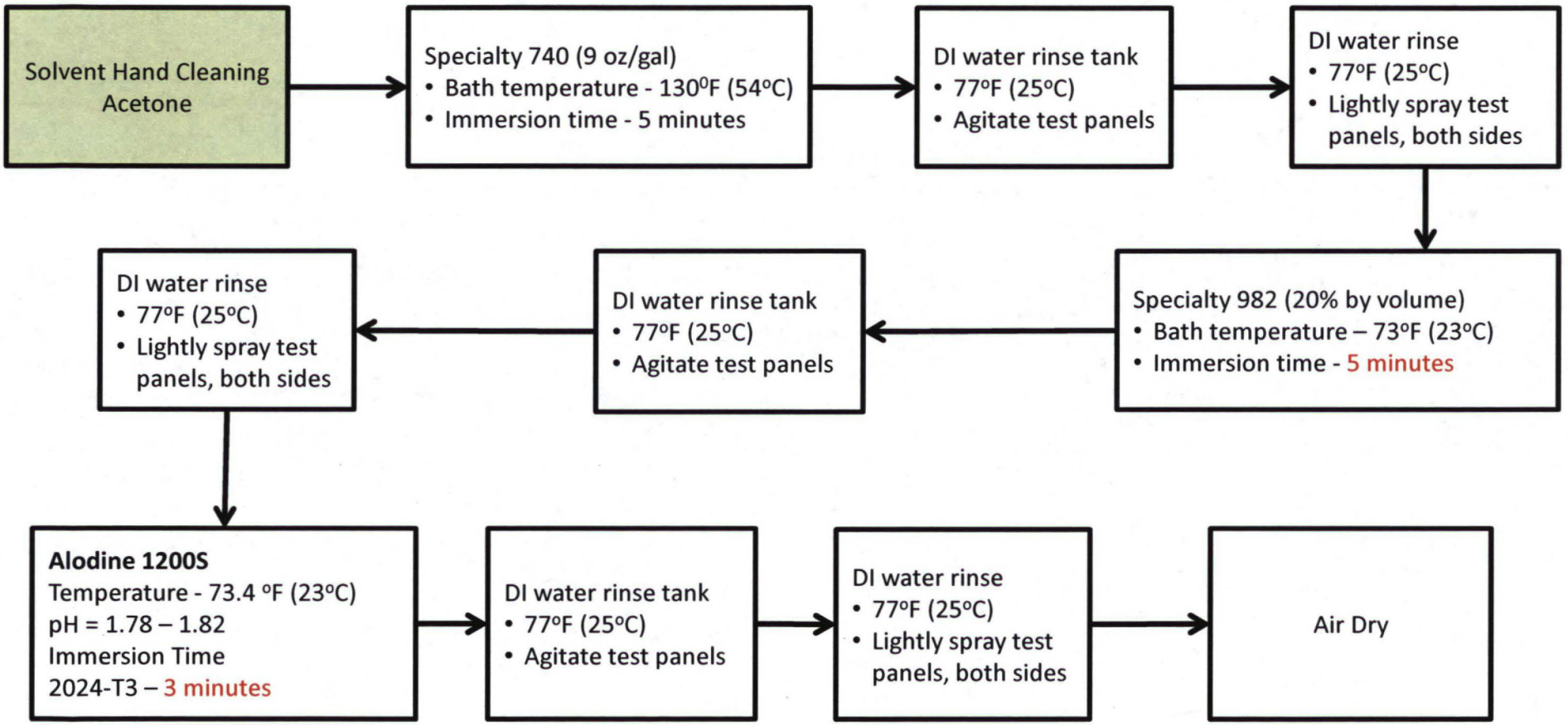
Representatives at Metalast were asked to review our test panels preparation process and procedures.

- Metalast Response: "One of the biggest of challenges of 2xxx series alloys is the differences in the alloying make up from batch to batch. We have often seen situations where one test group of 2024 test panels passes salt spray only to have the next set fail with no changes in the processing parameters.
- This is the primary motivating factor behind METALAST HPA 100. Since METALAST begun testing METALAST HPA-100, we has observed virtually no salt spray failures on 2024 in both, in house and third party testing performed in accordance with MIL-DTL 5541F.

# Test Panel Preparation Process Optimization {II}

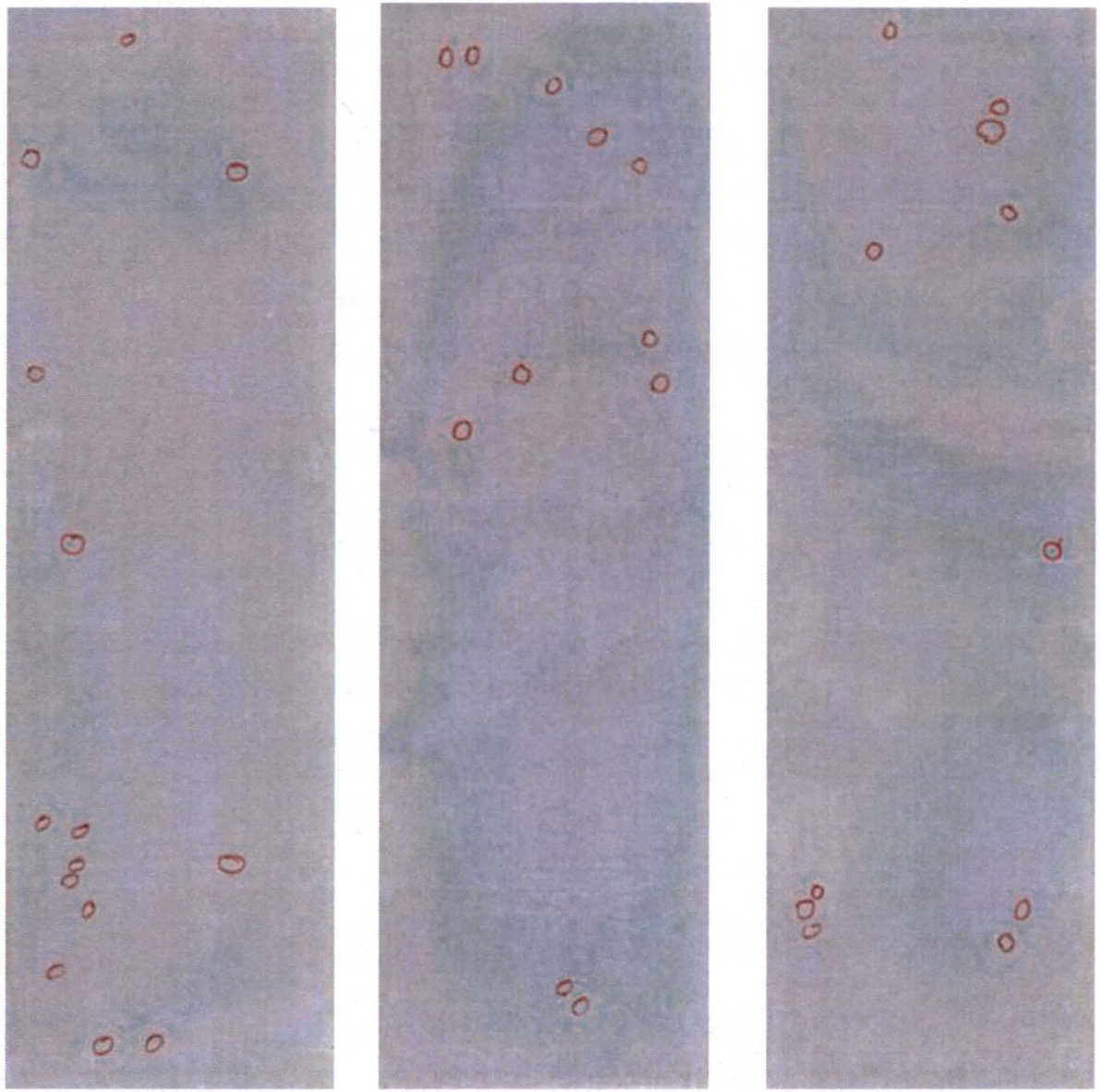
- Changing initial solvent cleaning process
- Adjusted concentration and pH of Alodine 1200S
- Modified SurTec 650C process

# Alodine 1200S



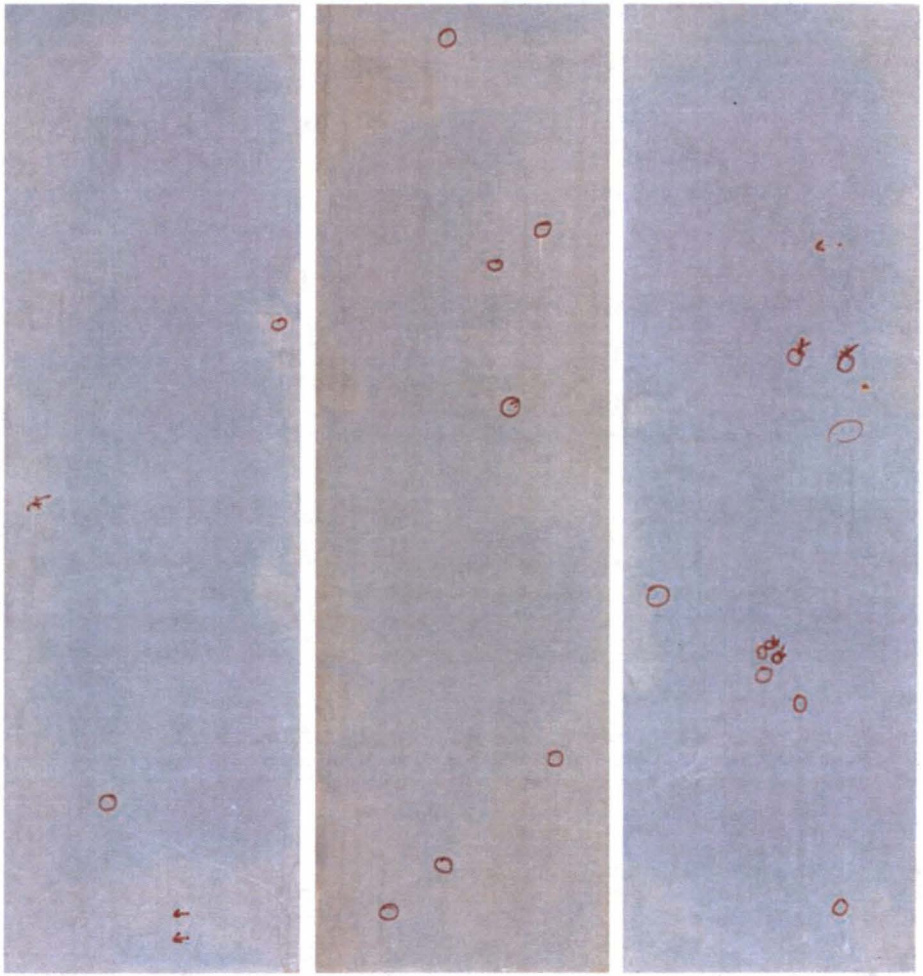
# Alodine 1200S

| 2024-T3 | @ 168 Hr | @ 336 Hr |
|---|---|---|
| 1200S 20 01 | 5+ | N/A |
| 1200S 20 02 | 3 | 5+ |
| 1200S 20 03 | 4 | 5+ |

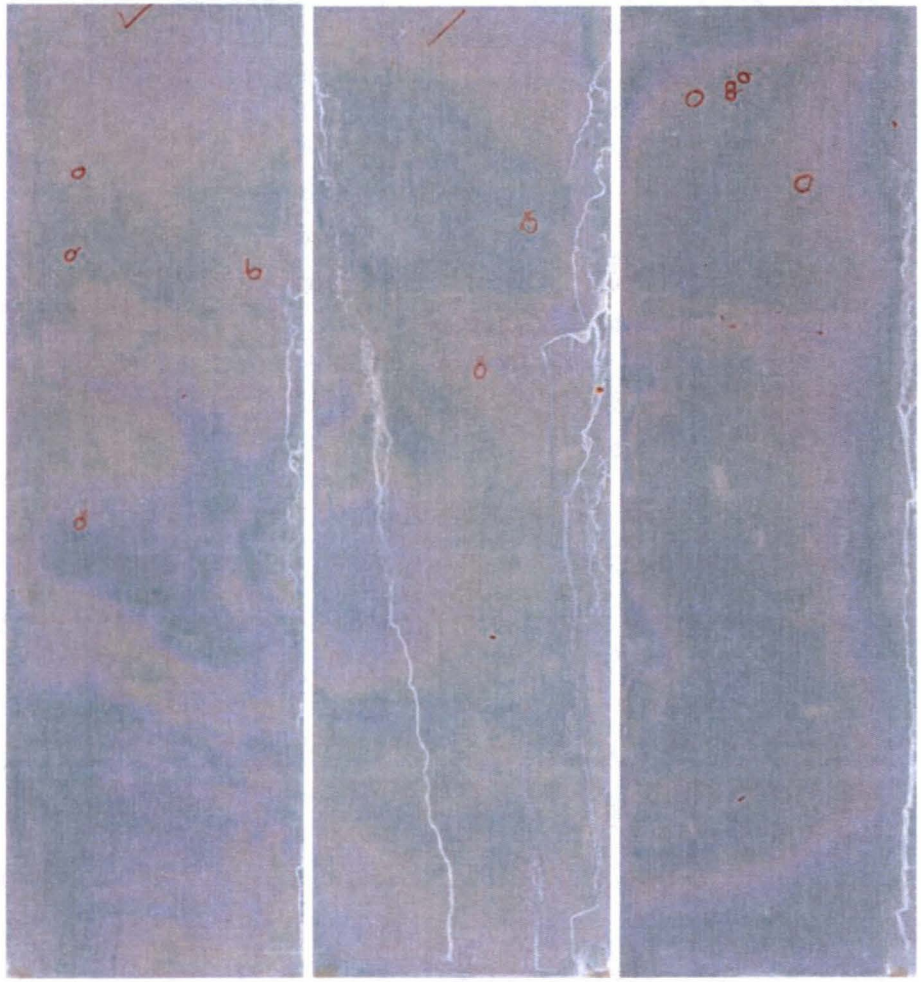


# Alodine 1200S

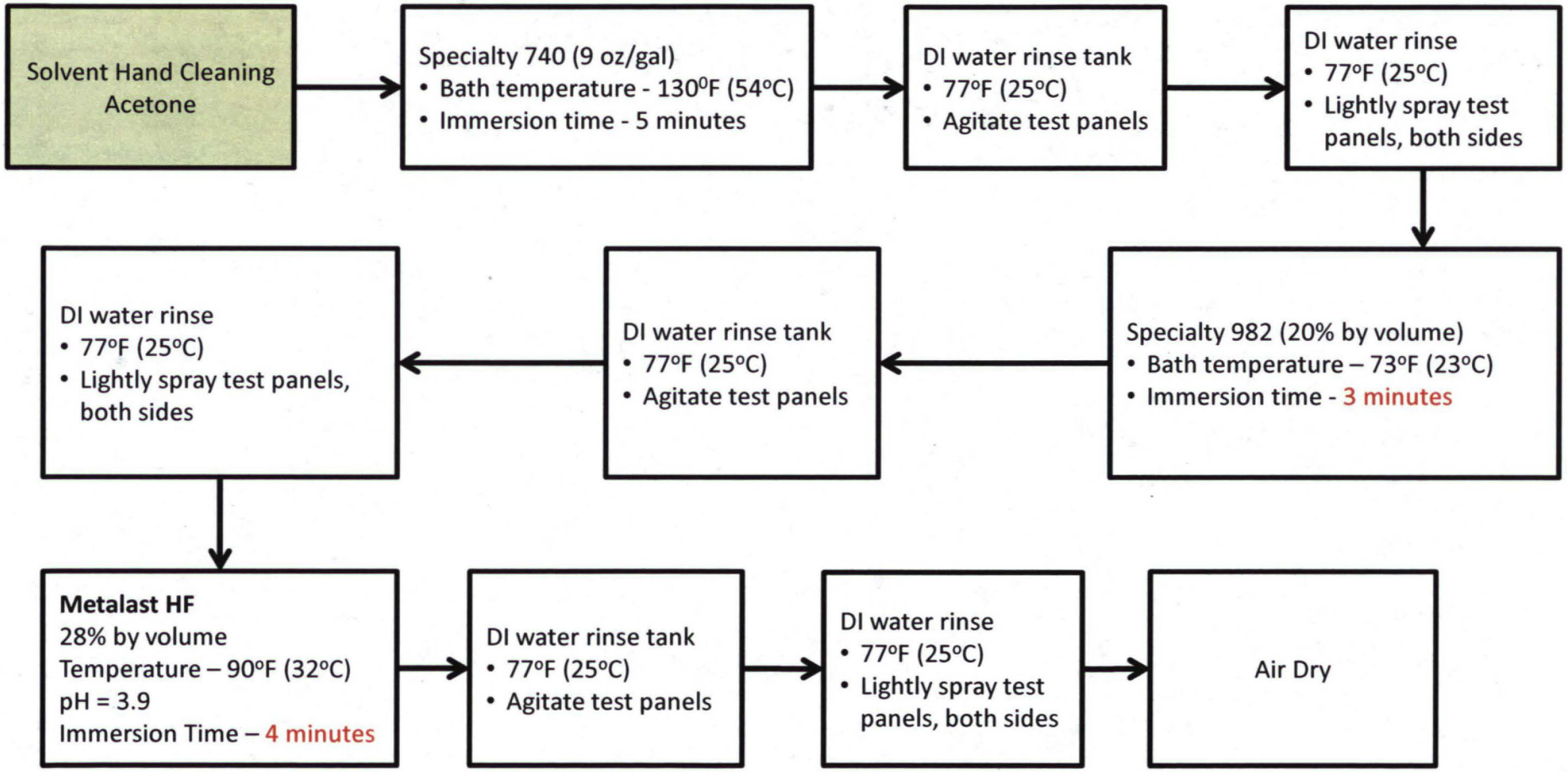
| 6061-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| 1200S 60 01 | 2 | 0 | 0 | 0 | 2 |
| 1200S 60 02 | 5+ | N/A | N/A | N/A | 5+ |
| 1200S 60 03 | 2 | 2 | 2 | 2 | 8 |



| 7075-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| 1200S 70 01 | 0 | 1 | 1 | 2 | 4 |
| 1200S 70 02 | 0 | 0 | 0 | 0 | 0 |
| 1200S 70 03 | 1 | 1 | 2 | 2 | 6 |

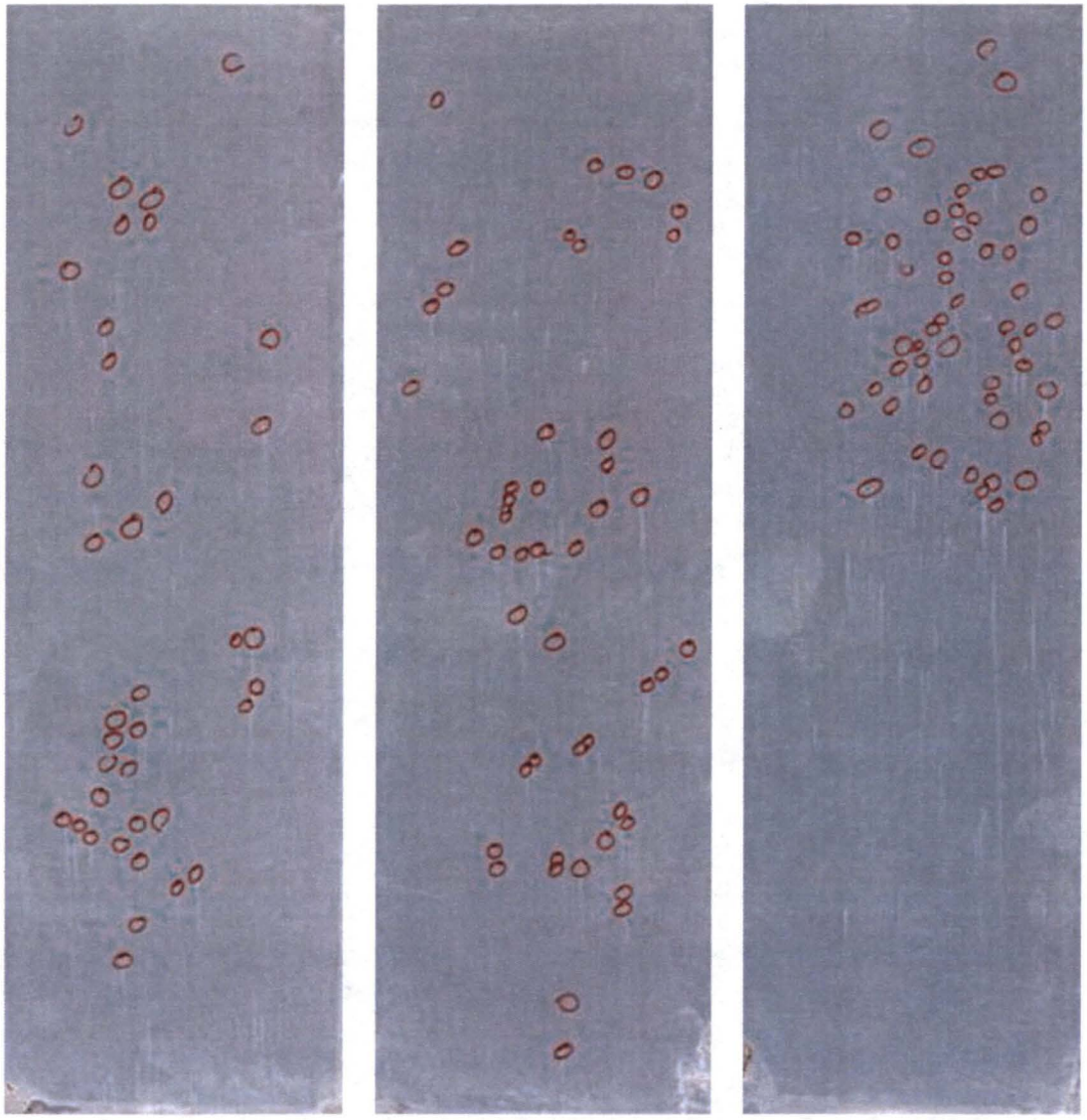


# Metalast TCP HF



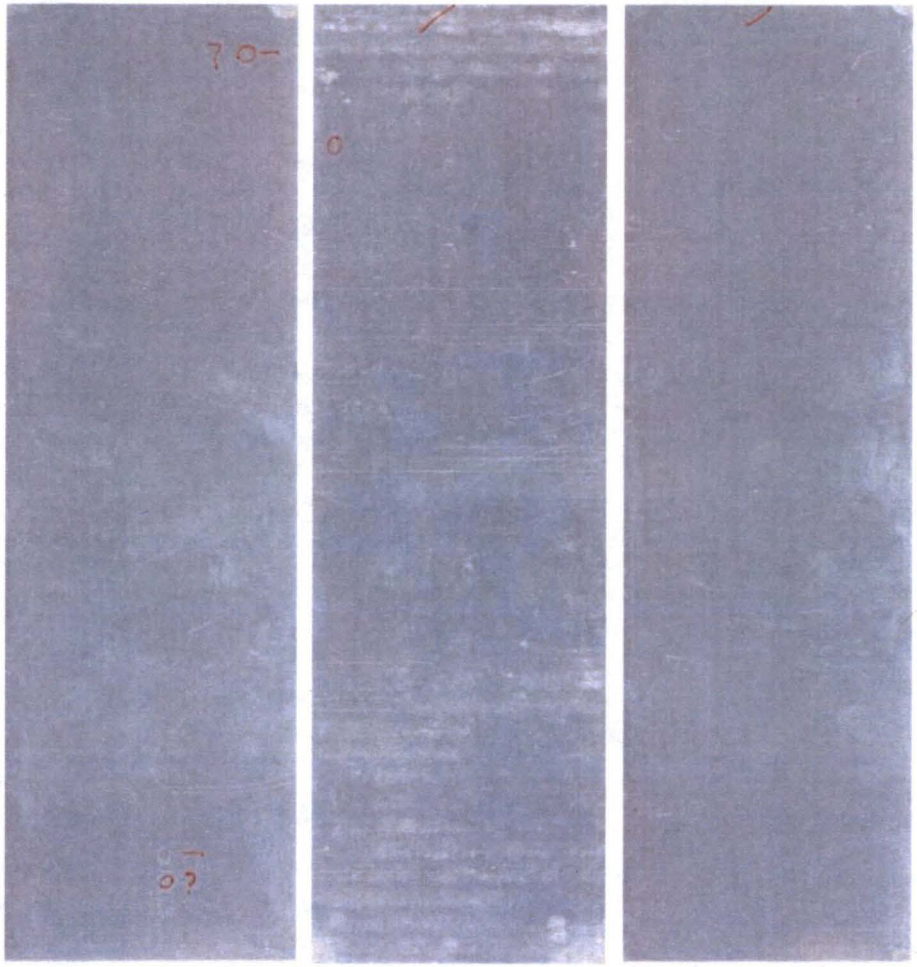
# Metalast TCP-HF

| 2024-T3 | @ 168 Hr | @ 336 Hr |
|---|---|---|
| MTL 20 01 | 5+ | N/A |
| MTL 20 02 | 5+ | N/A |
| MTL 20 03 | 5+ | N/A |

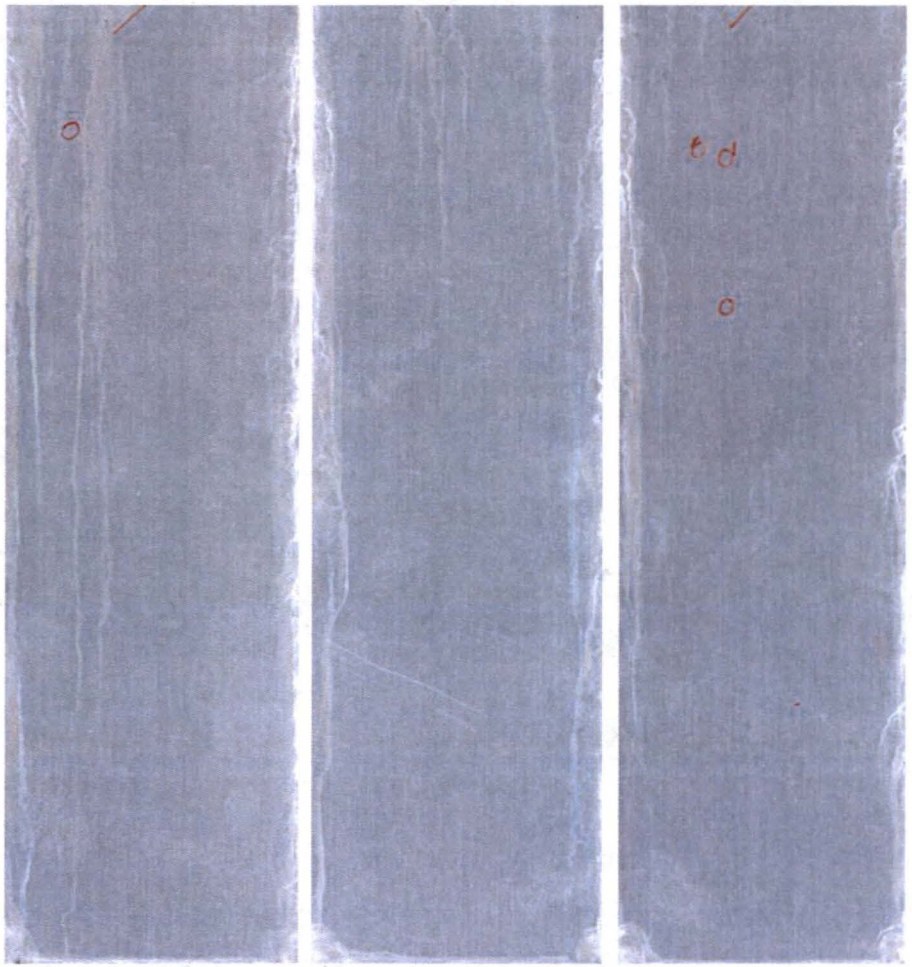


# Metalast TCP-HF

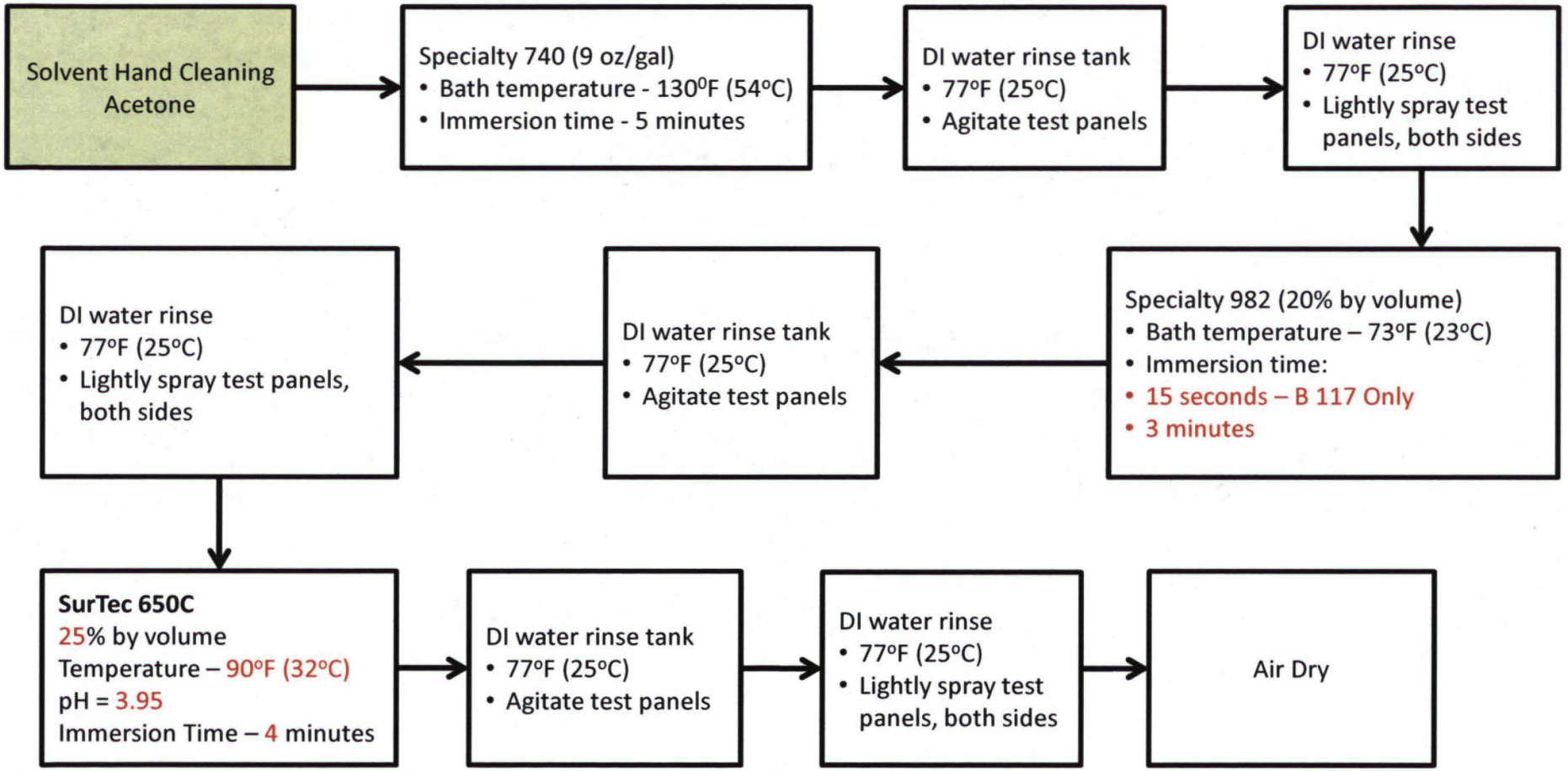
| 6061-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| MTL 60 01 | 0 | 0 | 0 | 0 | 0 |
| MTL 60 02 | 0 | 0 | 0 | 0 | 0 |
| MTL 60 03 | 0 | 0 | 0 | 0 | 0 |



| 7075-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| MTL 70 01 | 0 | 0 | 0 | 0 | 0 |
| MTL 70 02 | 0 | 0 | 0 | 0 | 0 |
| MTL 70 03 | 0 | 1 | 1 | 0 | 2 |

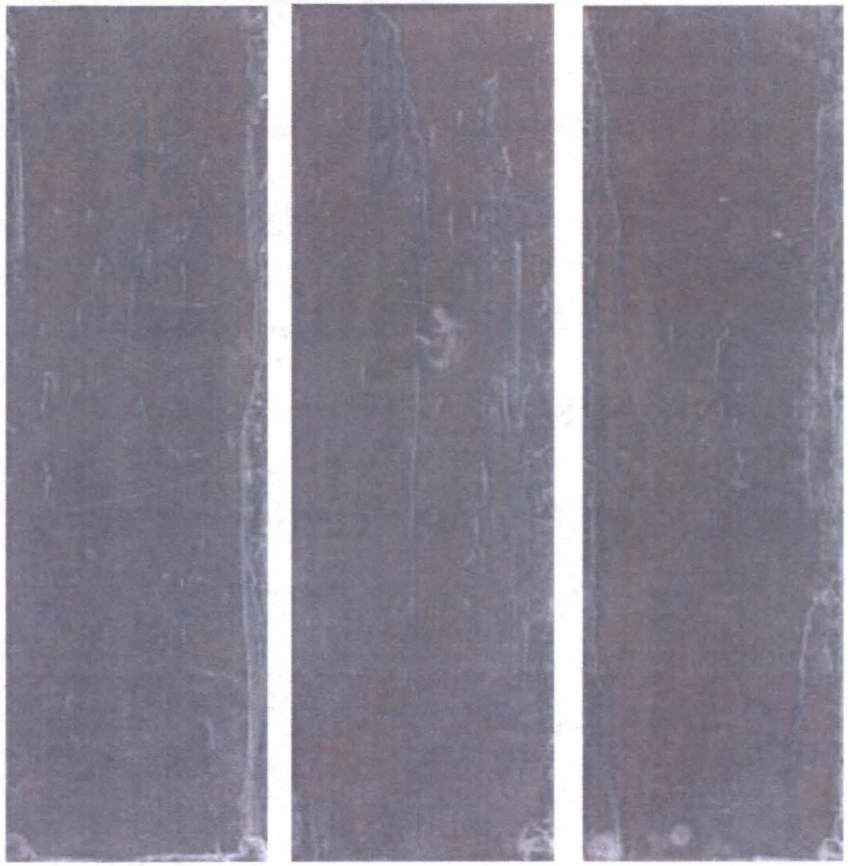


# SurTec 650C

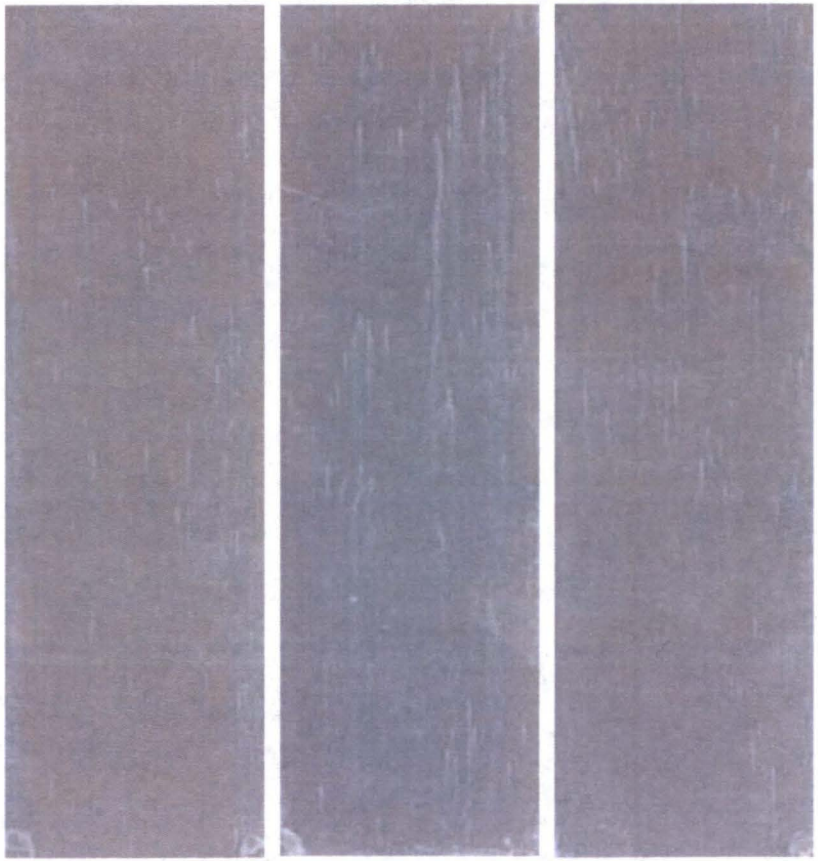

Solvent Hand Cleaning
Acetone
Specialty 740 (9 oz/gal)
• Bath temperature - 130°F (54°C)
• Immersion time - 5 minutes
DI water rinse tank
• 77°F (25°C)
• Agitate test panels
DI water rinse
• 77°F (25°C)
• Lightly spray test panels, both sides
Specialty 982 (20% by volume)
• Bath temperature – 73°F (23°C)
• Immersion time:
• 15 seconds – B 117 Only
• 3 minutes
DI water rinse tank
• 77°F (25°C)
• Agitate test panels
DI water rinse
• 77°F (25°C)
• Lightly spray test panels, both sides
SurTec 650C
25% by volume
Temperature – 90°F (32°C)
pH = 3.95
Immersion Time – 4 minutes
DI water rinse tank
• 77°F (25°C)
• Agitate test panels
DI water rinse
• 77°F (25°C)
• Lightly spray test panels, both sides
Air Dry

# SurTec 650C

| 2024-T3 | @ 168 Hr | @ 336 Hr |
|---|---|---|
| ST 20 01-15 | 5+ | N/A |
| ST 20 02-15 | 5+ | N/A |
| ST 20 03-15 | 5+ | N/A |



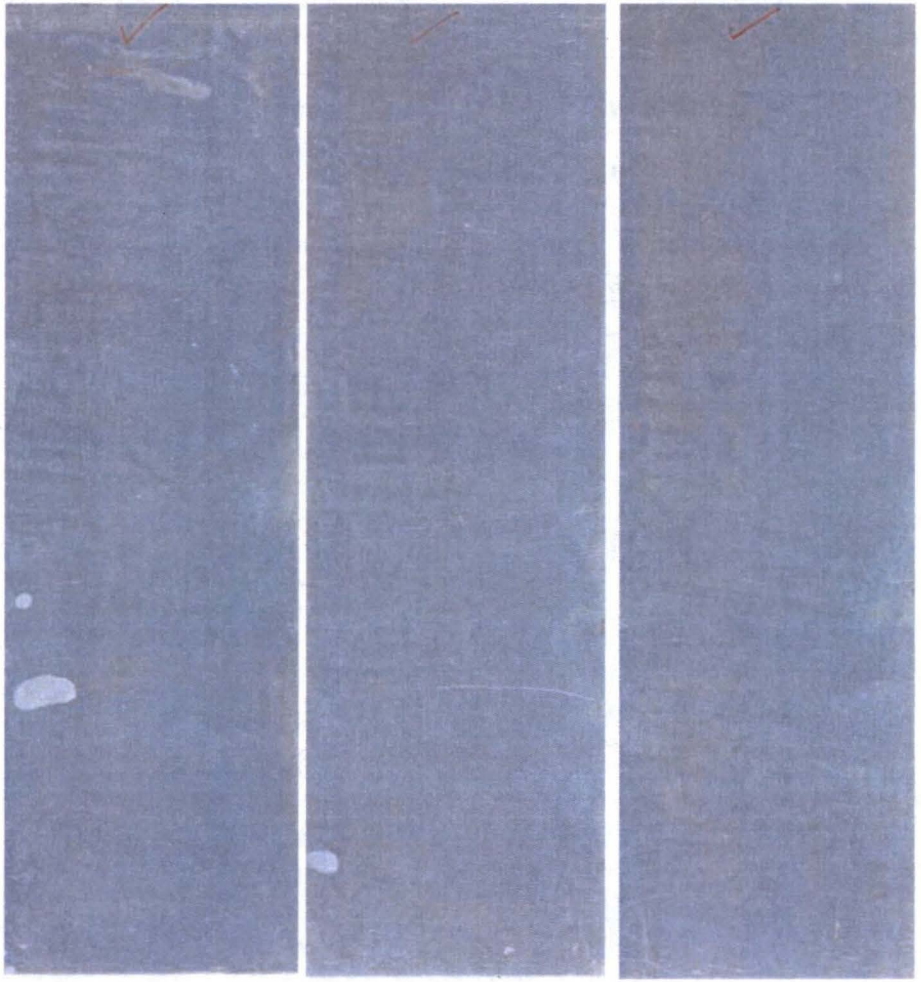
| 2024-T3 | @ 168 Hr | @ 336 Hr |
|---|---|---|
| ST 20 01 | 5+ | N/A |
| ST 20 02 | 5+ | N/A |
| ST 20 03 | 5+ | N/A |

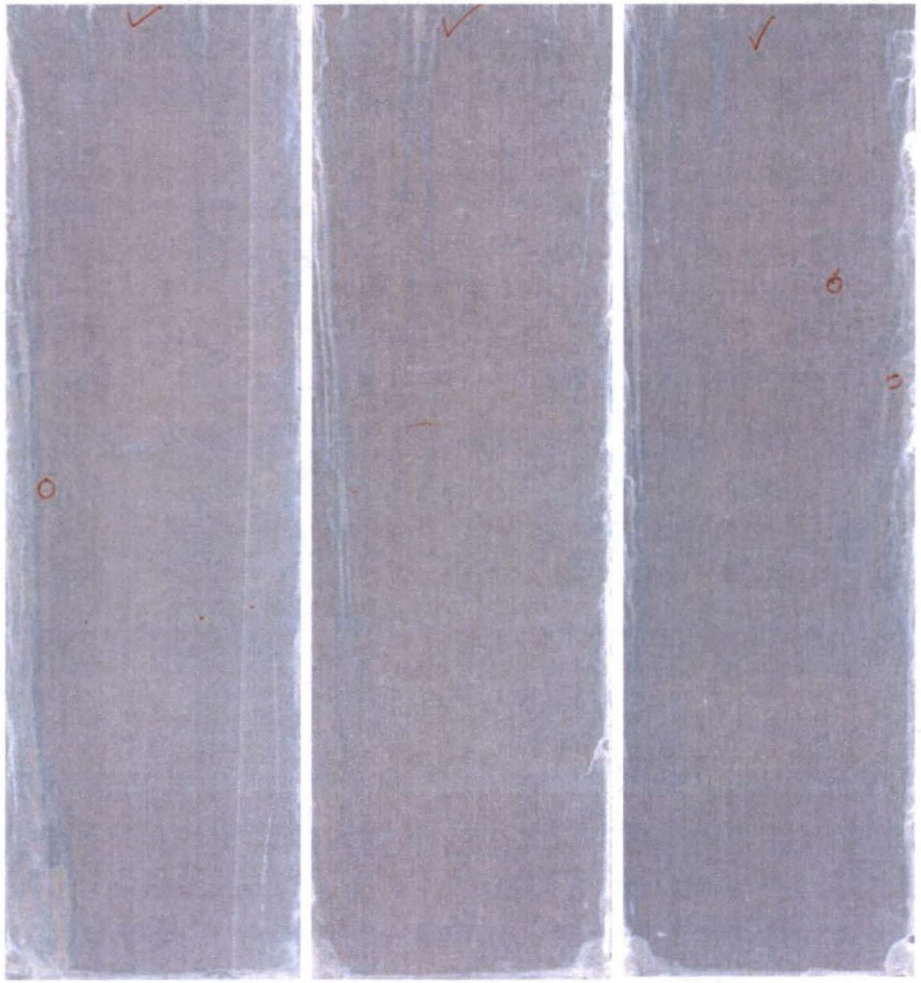


# SurTec 650C

| 6061-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| ST 60 01 | 0 | 0 | 0 | 0 | 0 |
| ST 60 02 | 0 | 0 | 0 | 0 | 0 |
| ST 60 03 | 0 | 0 | 0 | 0 | 0 |

| 7075-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| ST 70 01 | 0 | 1 | 0 | 0 | 1 |
| ST 70 02 | 0 | 0 | 0 | 0 | 0 |
| ST 70 03 | 0 | 1 | 0 | 0 | 1 |

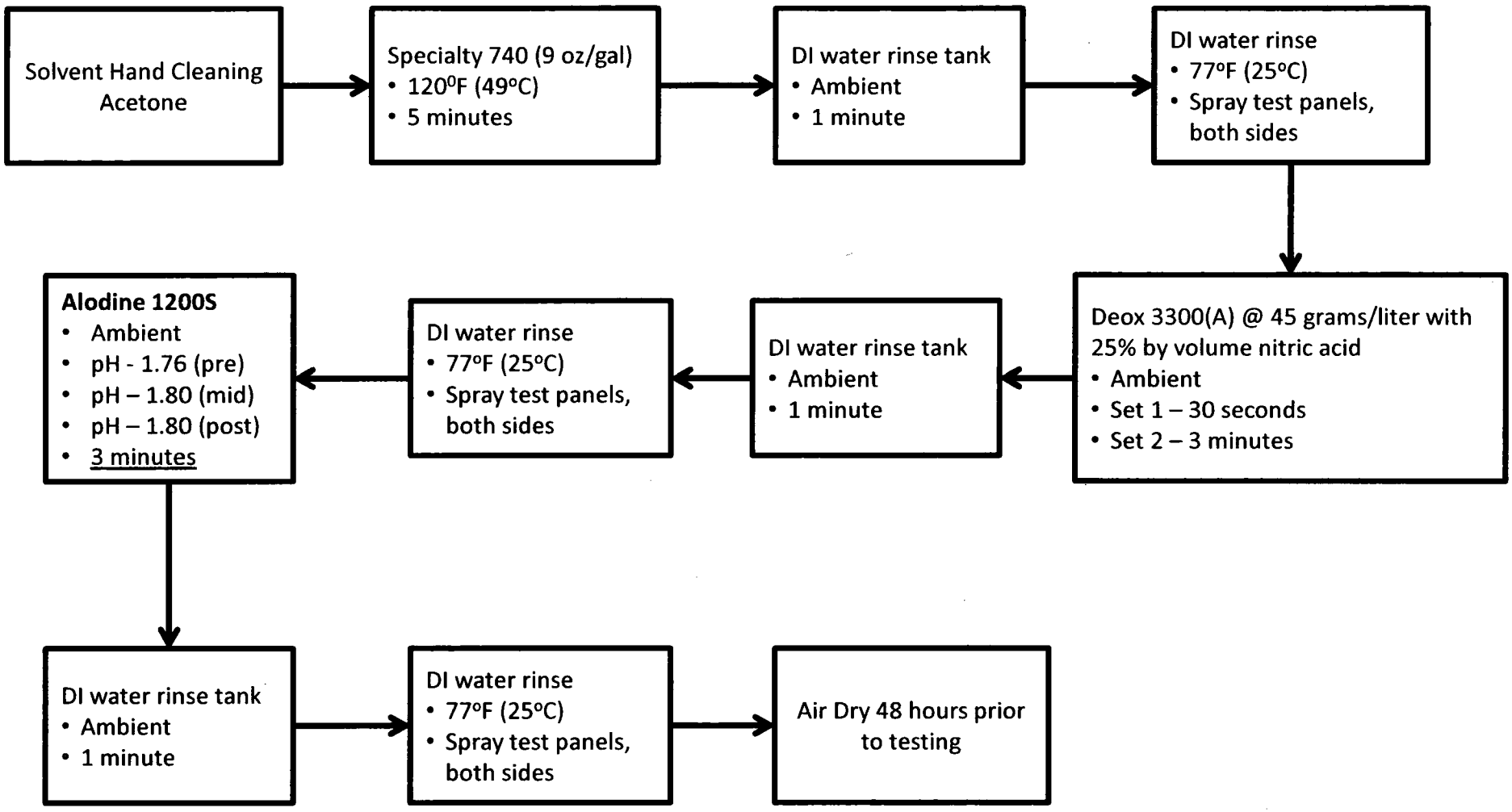




# Test Panel Preparation Process Optimization {III}

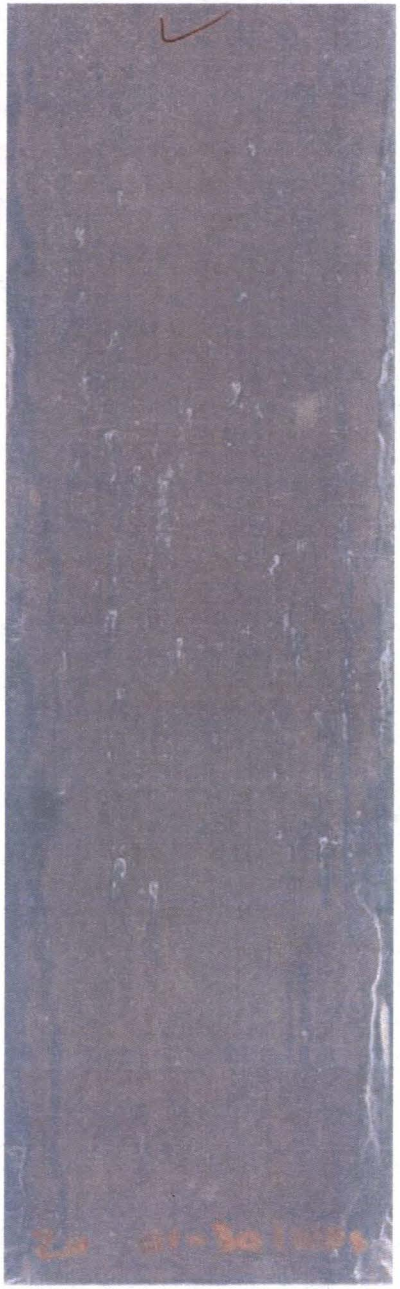
- Changing deoxidizer to an iron free based deoxidizer {Metalast Deox 3300(A)}
- Using new batch of Alodine 1200S
- Using new batch of Metalast HF with HPA-100 additive
- Using Alodine 5923 plus, from Henkel Europe

# Pretreatment Process: Alodine 1200S



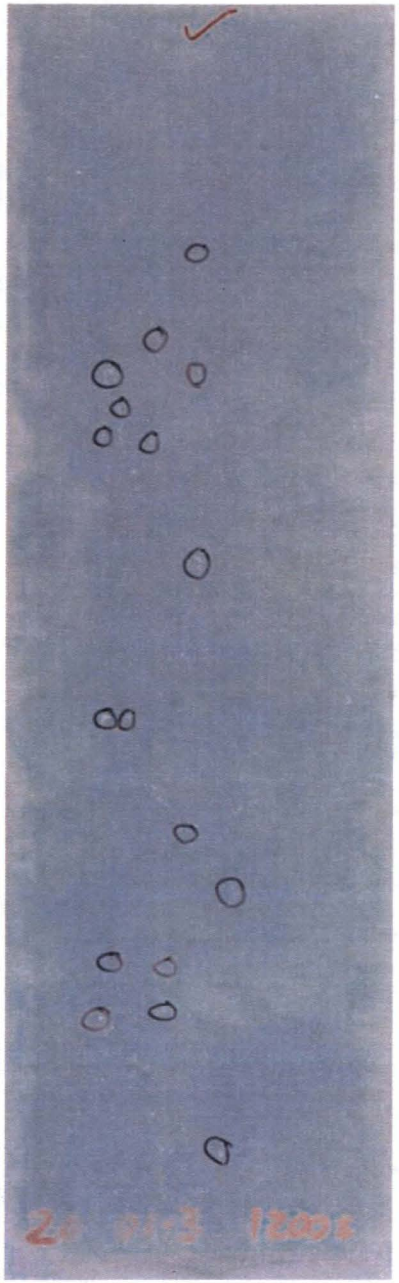
# Alodine 1200S

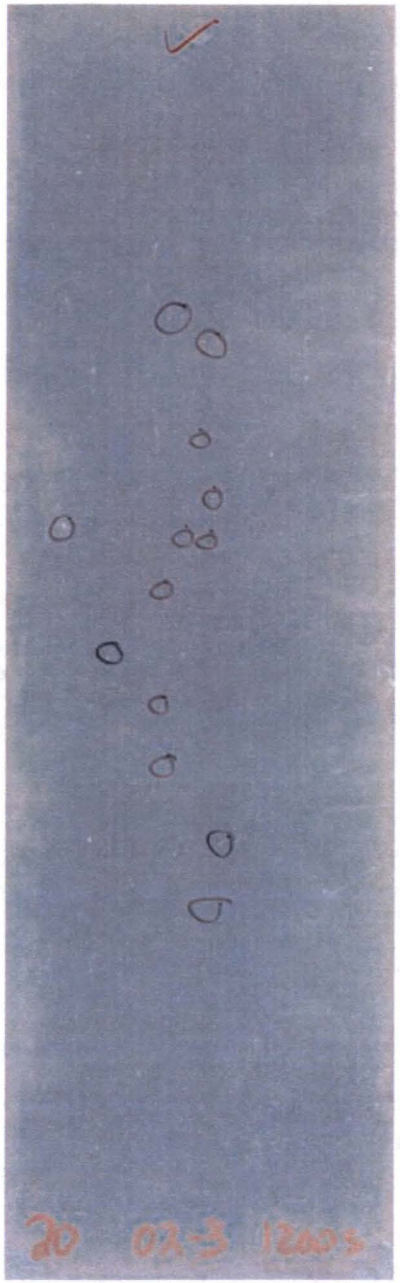
| 2024-T3 | @ 168 | @ 336 | @ 504 |
|---|---|---|---|
| 1200S 20 01 30 | 0 | 0 | 20+ |
| 1200S 20 02 30 | 0 | 0 | 20+ |
| 1200S 20 03 30 | 0 | 0 | 20+ |

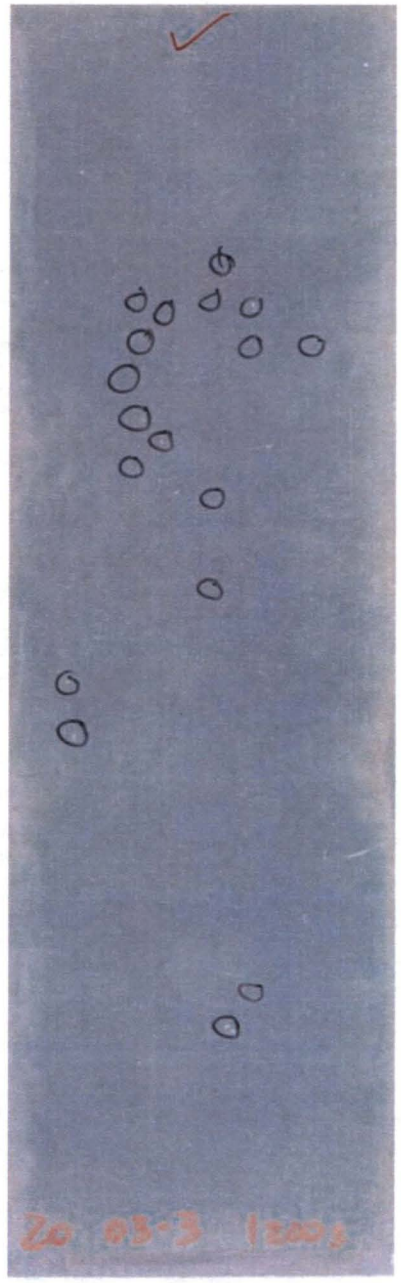


# Alodine 1200S

| 2024-T3 | @ 168 | @ 336 | @ 504 |
|---|---|---|---|
| 1200S 20 01 3 | 0 | 0 | 20+ |
| 1200S 20 02 3 | 0 | 0 | 20+ |
| 1200S 20 03 3 | 0 | 0 | 20+ |

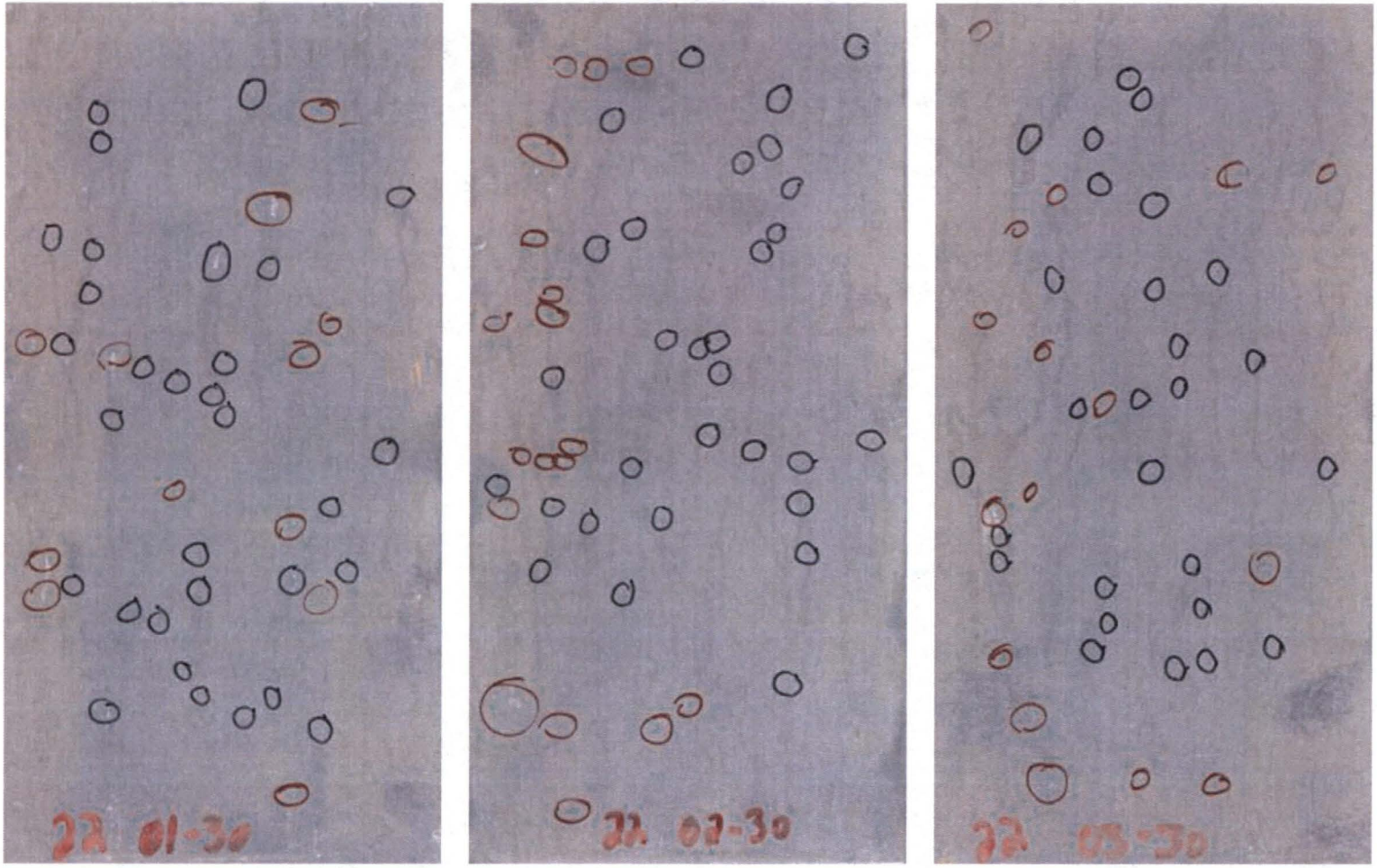


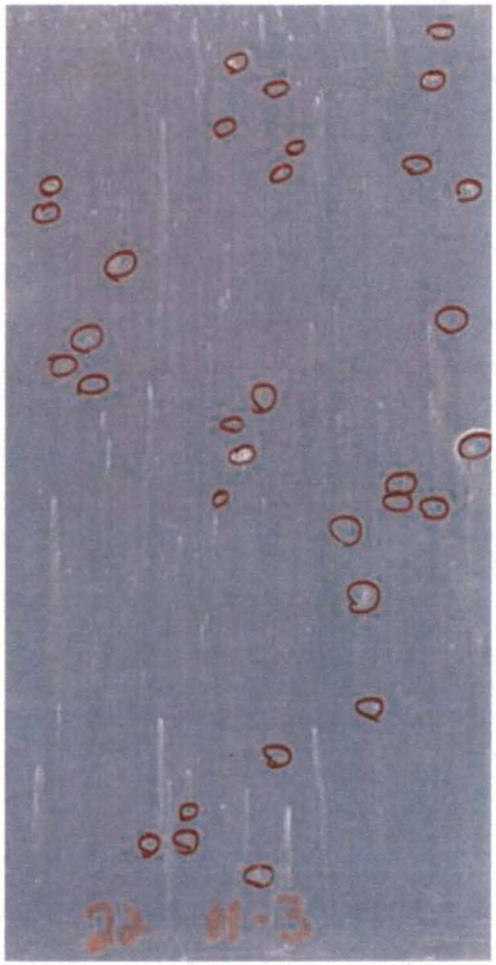
Alodine 1200S

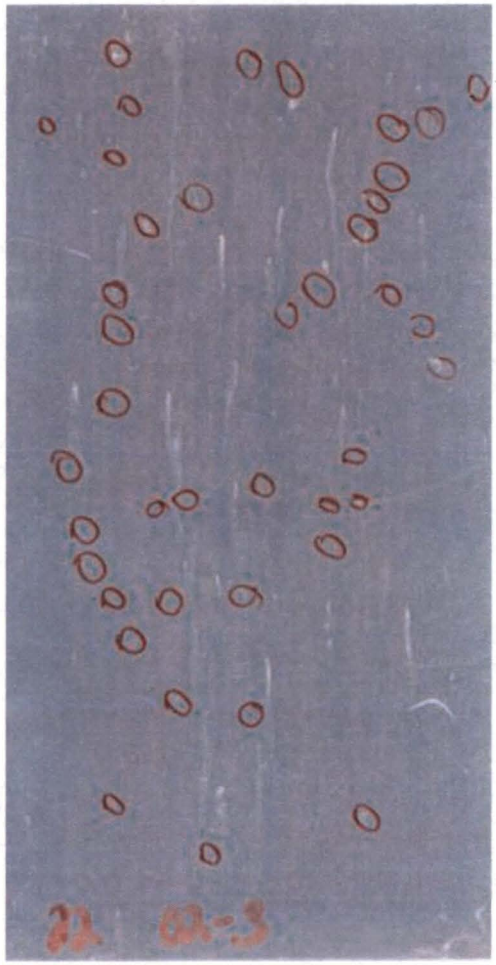
| 2219 | @ 168 | @ 336 |
|---|---|---|
| 1200S 22 01 30 | 12 | 20+ |
| 1200S 22 02 30 | 18 | 20+ |
| 1200S 22 03 30 | 16 | 20+ |

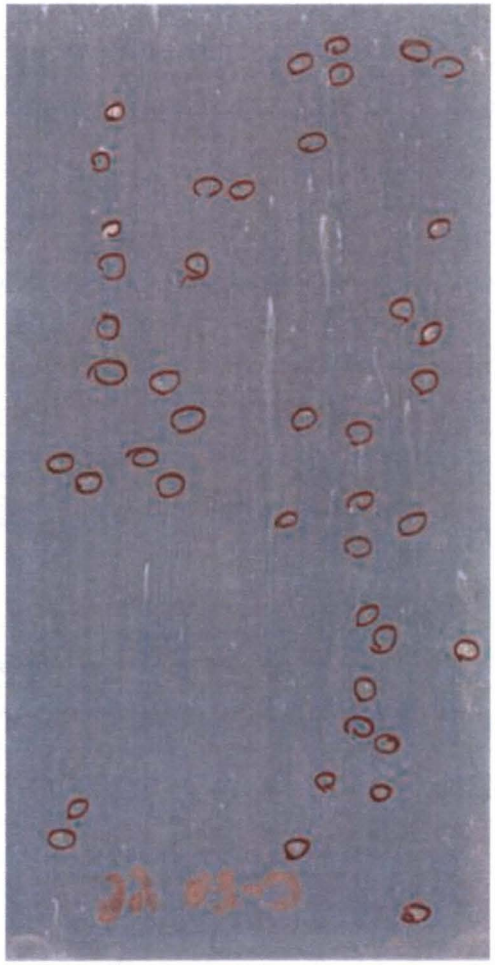


# Alodine 1200S

| 2219 | @ 168 | @ 336 |
|---|---|---|
| 1200S 22 01 3 | 32 | 50+ |
| 1200S 22 02 3 | 41 | 50+ |
| 1200S 22 03 3 | 43 | 50+ |



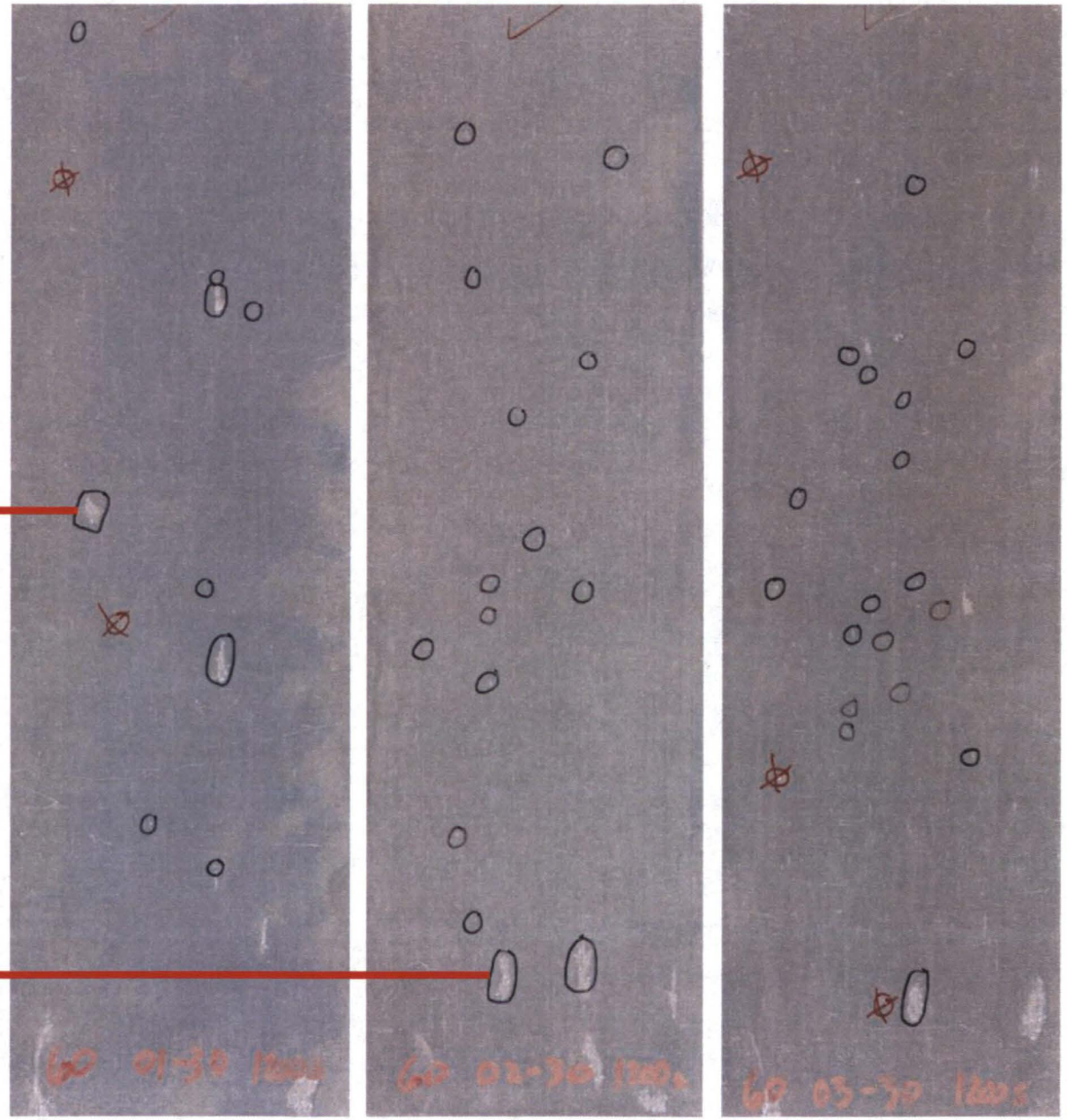



# Alodine 1200S

| 6061-T6 | @ 168 | @ 336 | @ 504 |
|---|---|---|---|
| 1200S 60 01 30 | 0 | 0 | *5+ |
| 1200S 60 02 30 | 0 | 0 | *10+ |
| 1200S 60 03 30 | 0 | 0 | *10+ |

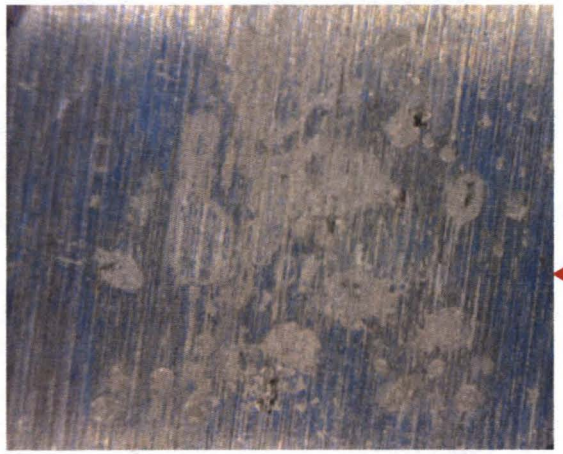
* Large spots / corrosion clusters

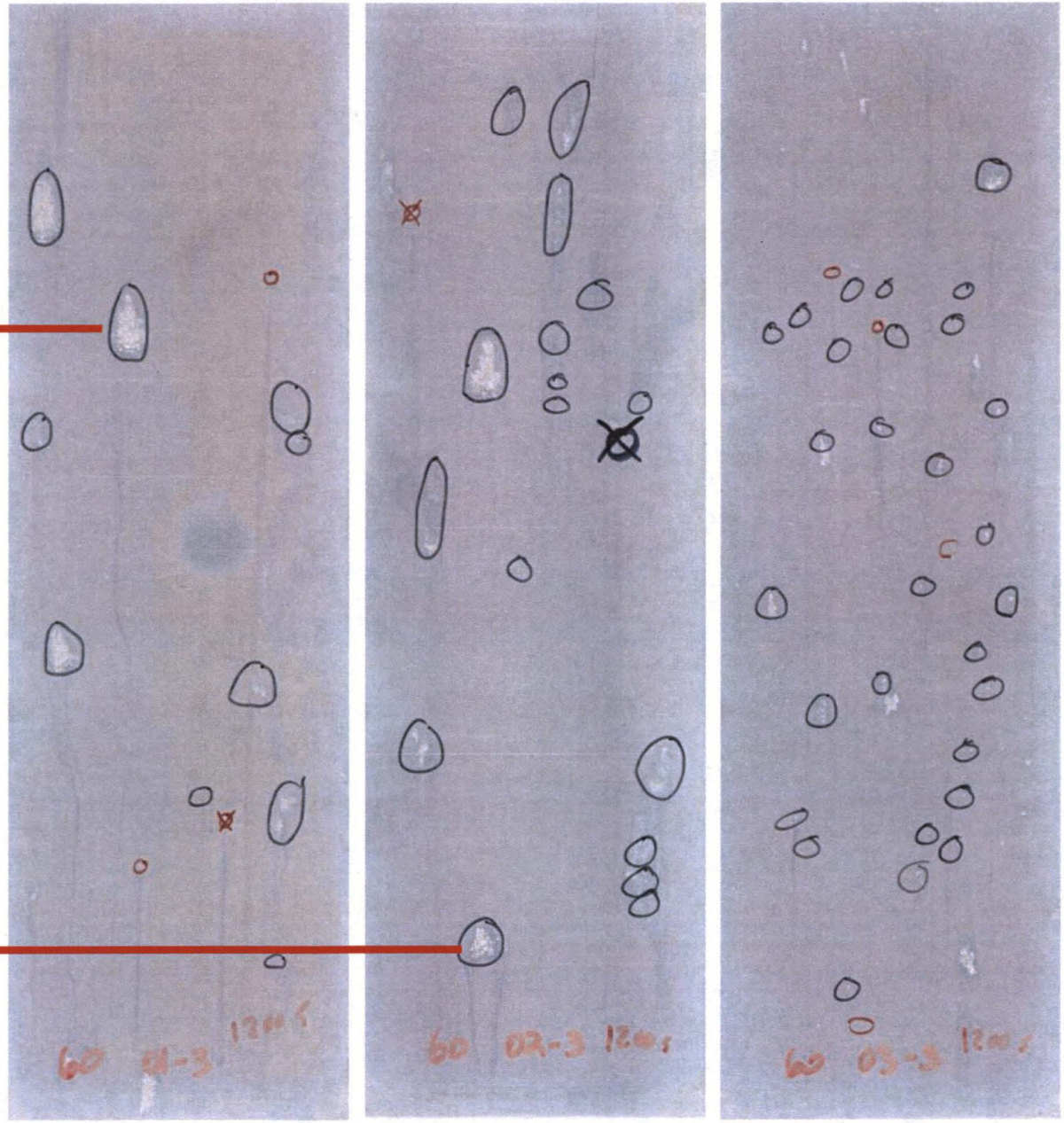


# Alodine 1200S

| 6061-T6 | @ 168 | @ 336 | @ 504 |
|---|---|---|---|
| 1200S 60 01 3 | 2 | 0 | *5+ |
| 1200S 60 02 3 | 0 | 0 | *10+ |
| 1200S 60 03 3 | 4 | 0 | 20+ |

* Large spots / corrosion clusters

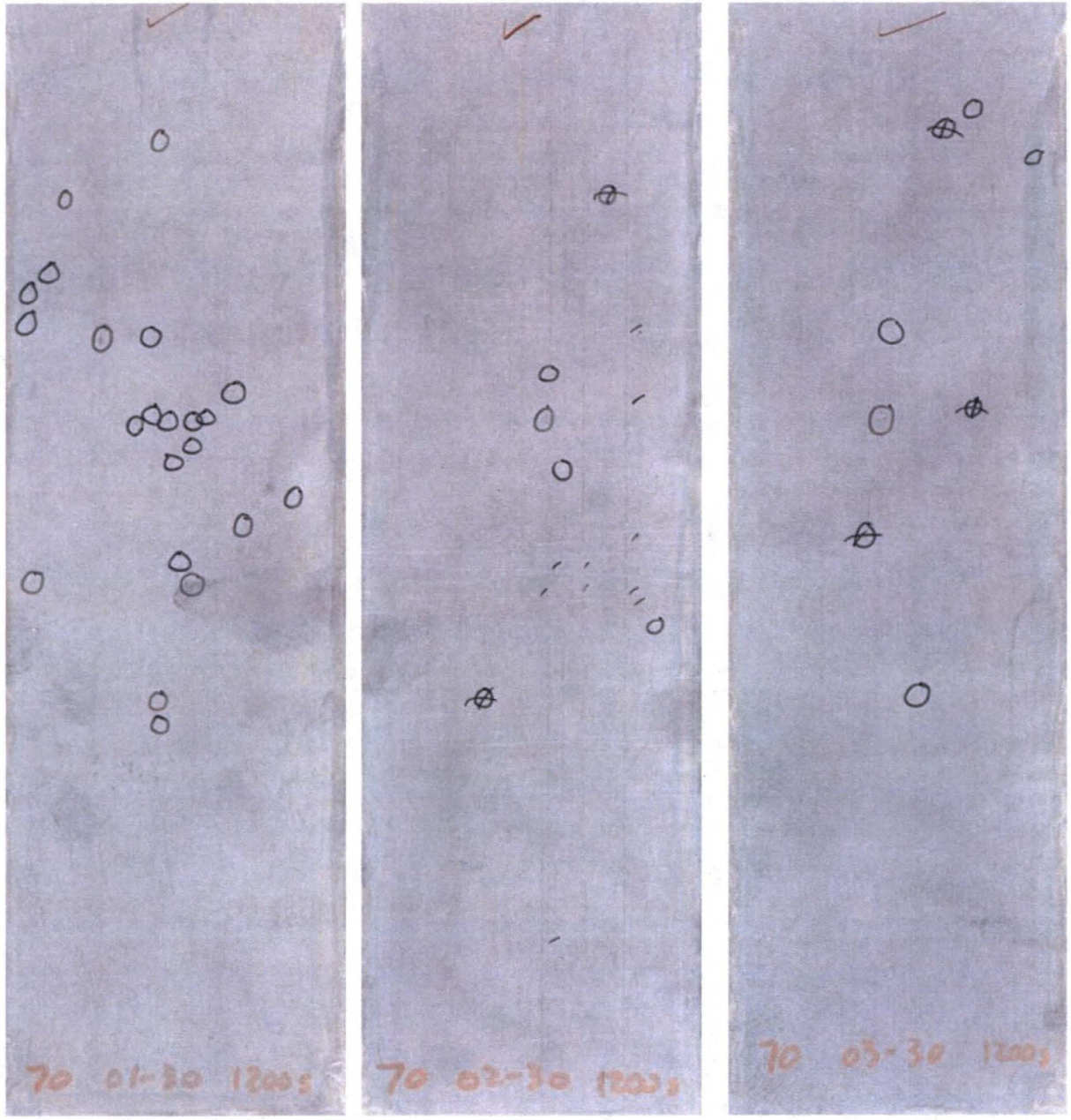




# Alodine 1200S

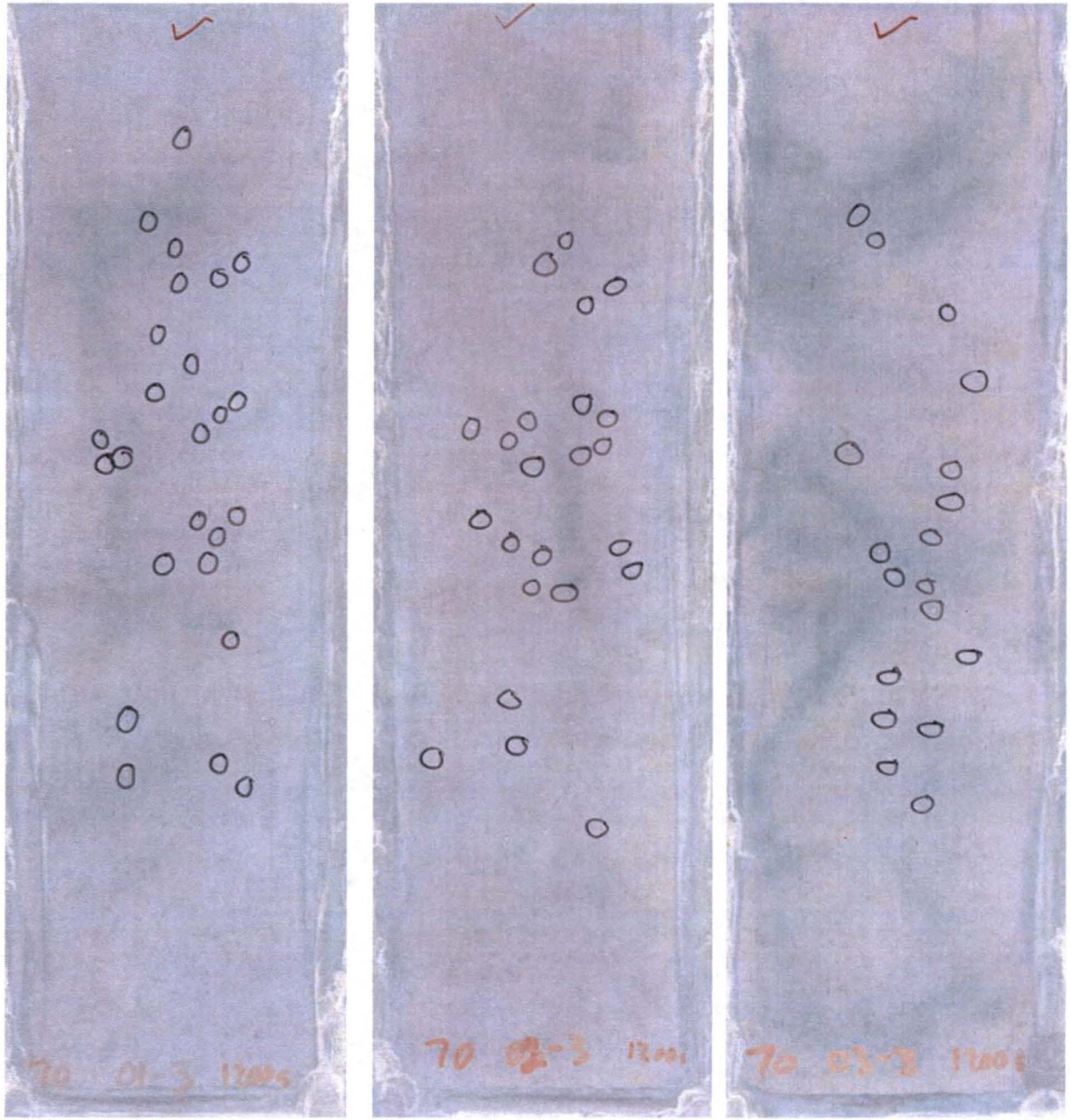
| 7075-T6 | @ 168 | @ 336 | @ 504 |
|---|---|---|---|
| 1200S 70 01 30 | 0 | 0 | 20+ |
| 1200S 70 02 30 | 0 | 0 | 4* |
| 1200S 70 03 30 | 0 | 0 | 5 |

* Test panel has numerous scratches with corrosion

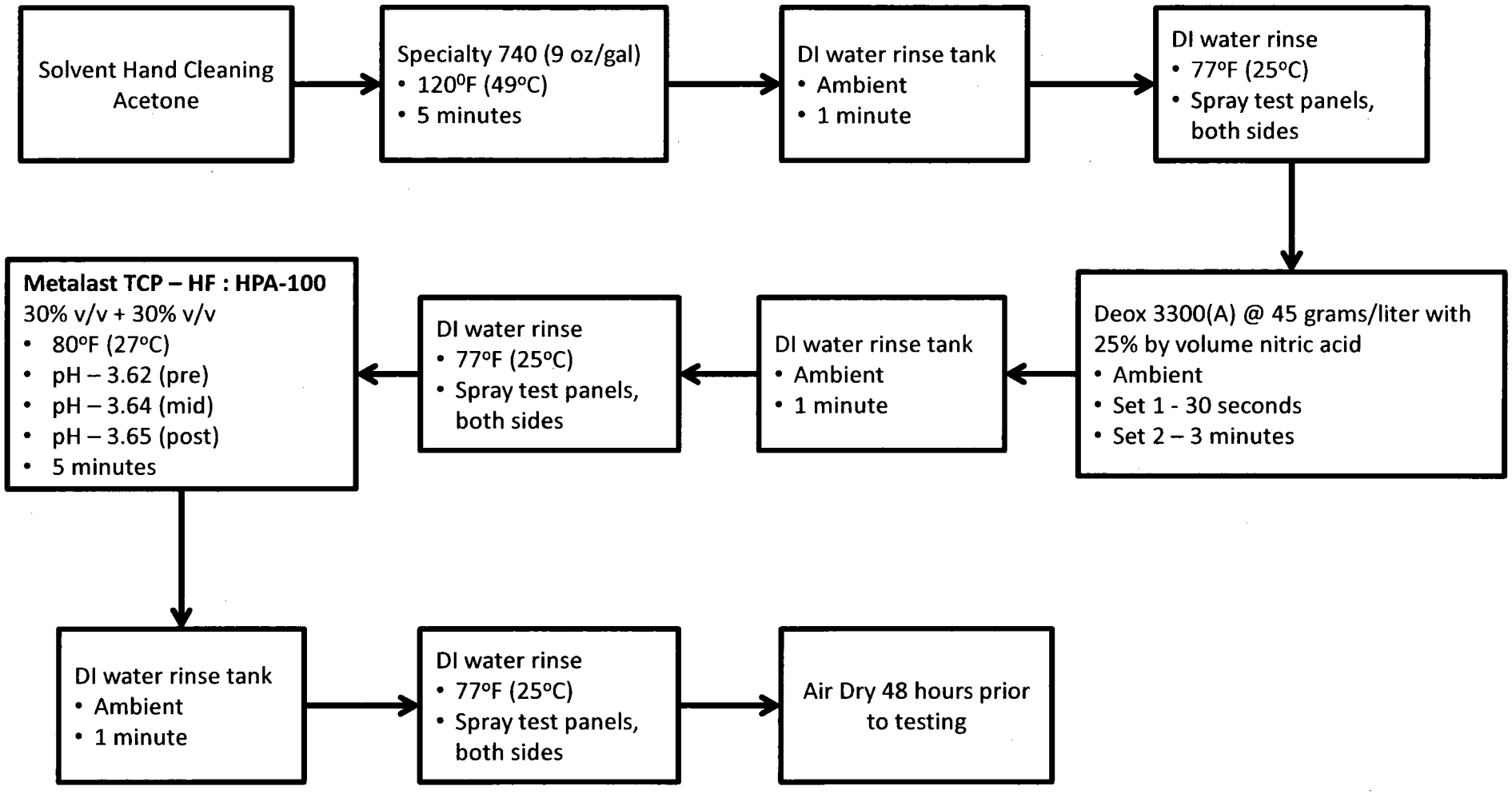


# Alodine 1200S

| 7075-T6 | @ 168 | @ 336 | @ 504 |
|---|---|---|---|
| 1200S 70 01 3 | 0 | 0 | 20+ |
| 1200S 70 02 3 | 0 | 0 | 20+ |
| 1200S 70 03 3 | 0 | 0 | 20+ |

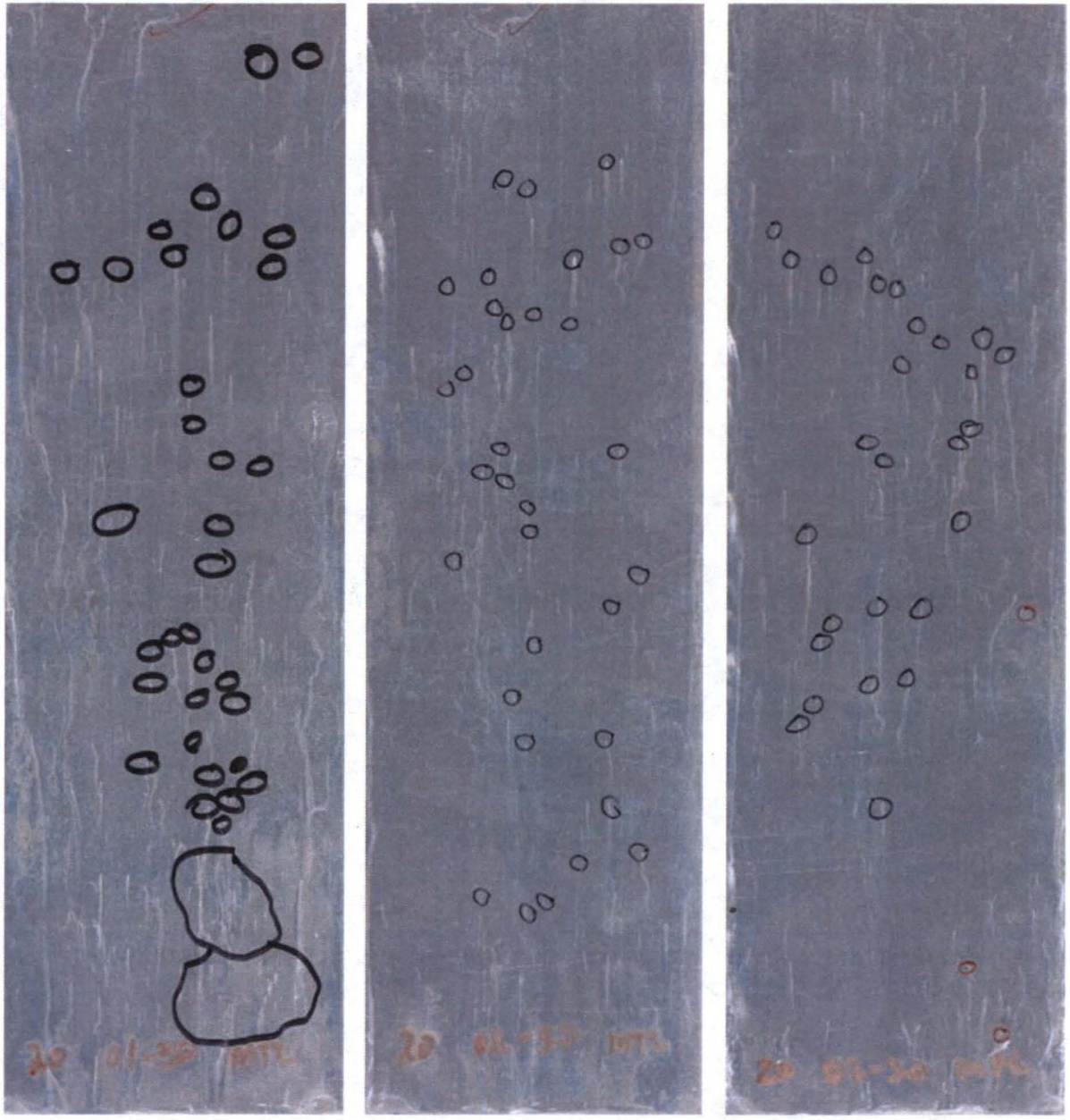


# Pretreatment Process: Metalast HF HPA-100



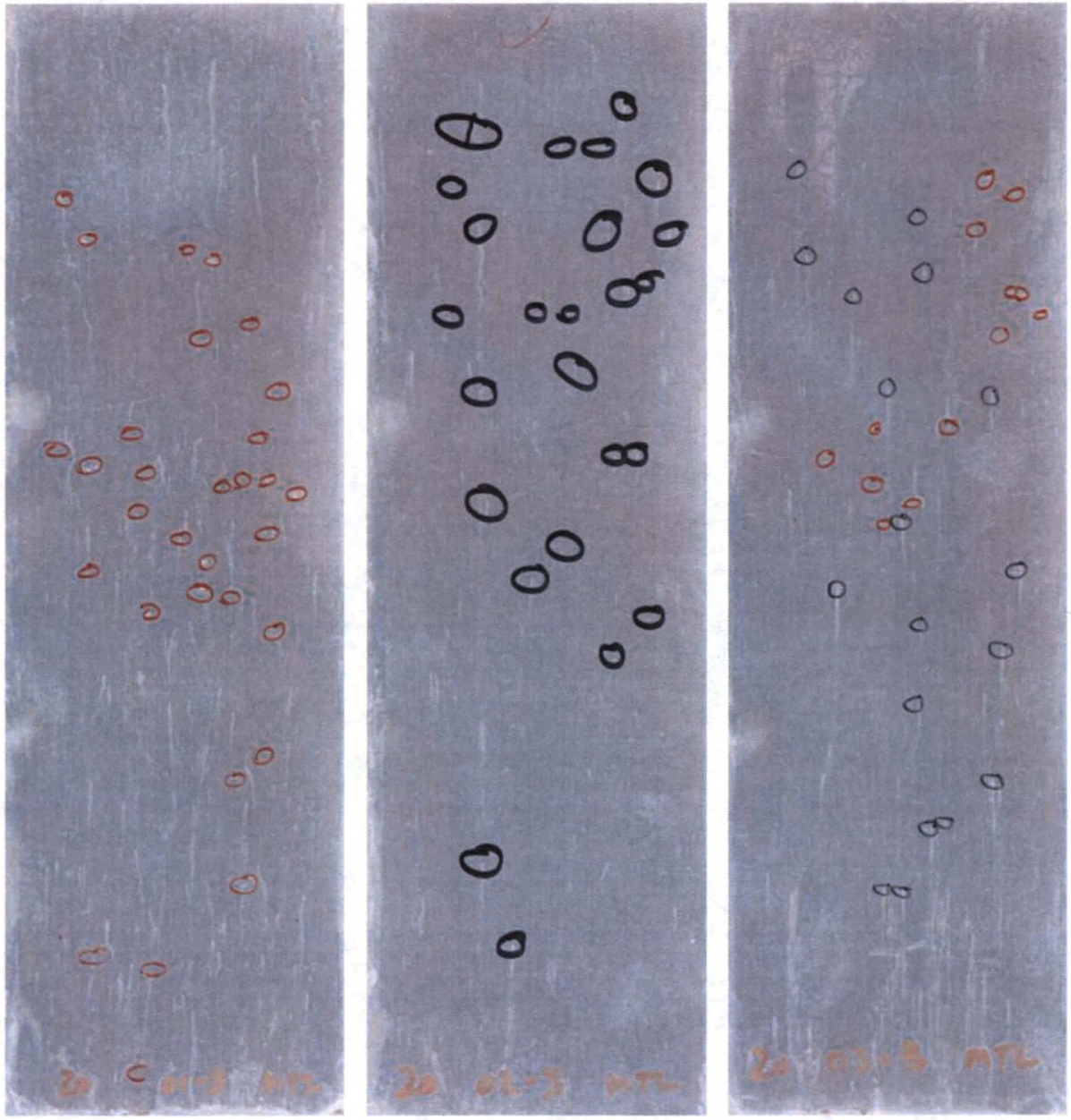
# Metalast HF HPA-100

| **2024-T3** | @ 168 | @ 336 |
|---|---|---|
| MTL 20 01 30 | 0 | 20+ |
| MTL 20 02 30 | 0 | 20+ |
| MTL 20 03 30 | 2 | 20+ |



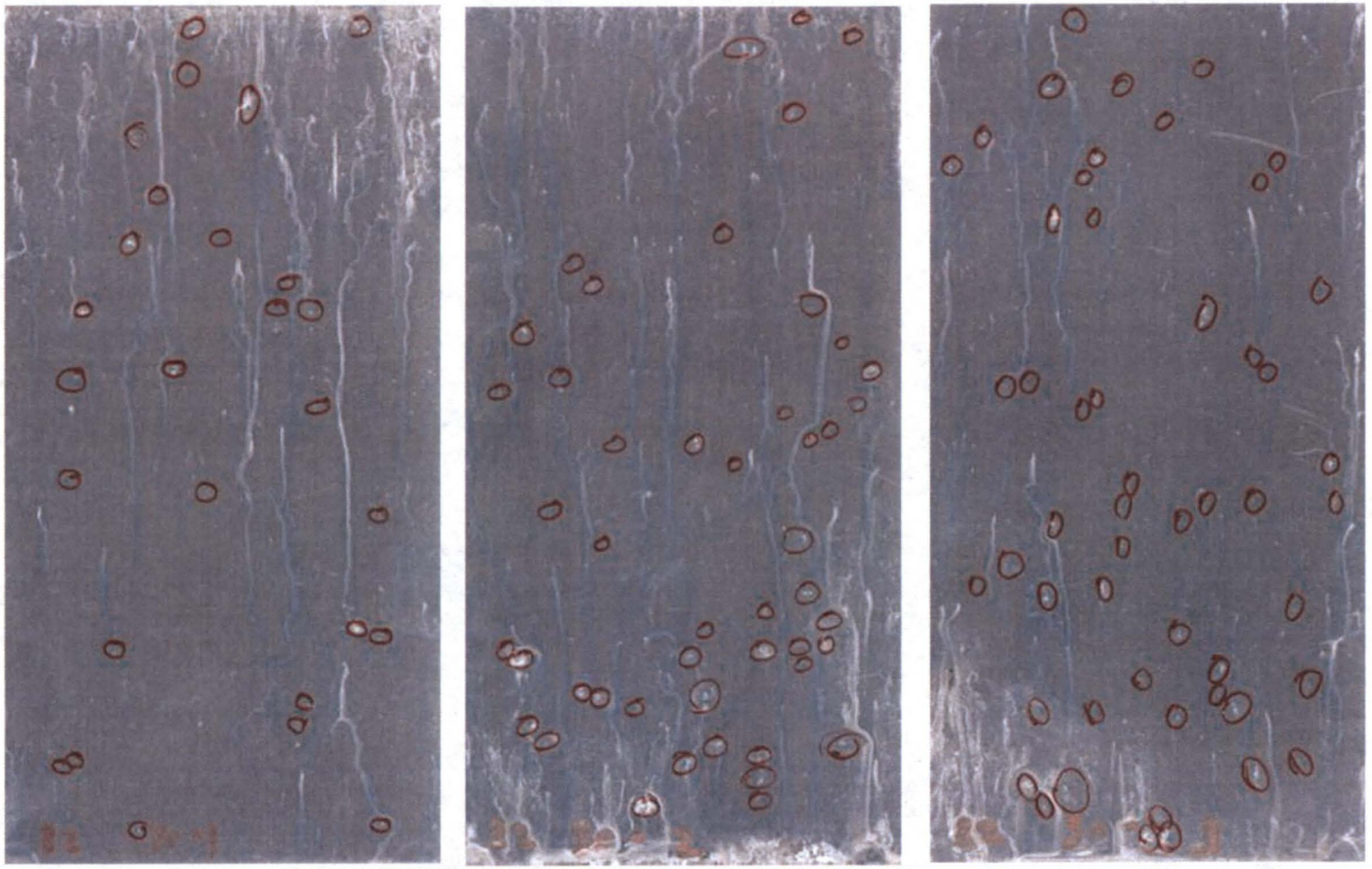
# Metalast HF HPA-100

| 2024-T3 | @ 168 | @ 336 |
|---|---|---|
| MTL 20 01 3 | 31 | 20+ |
| MTL 20 02 3 | 0 | 20+ |
| MTL 20 03 3 | 12 | 20+ |



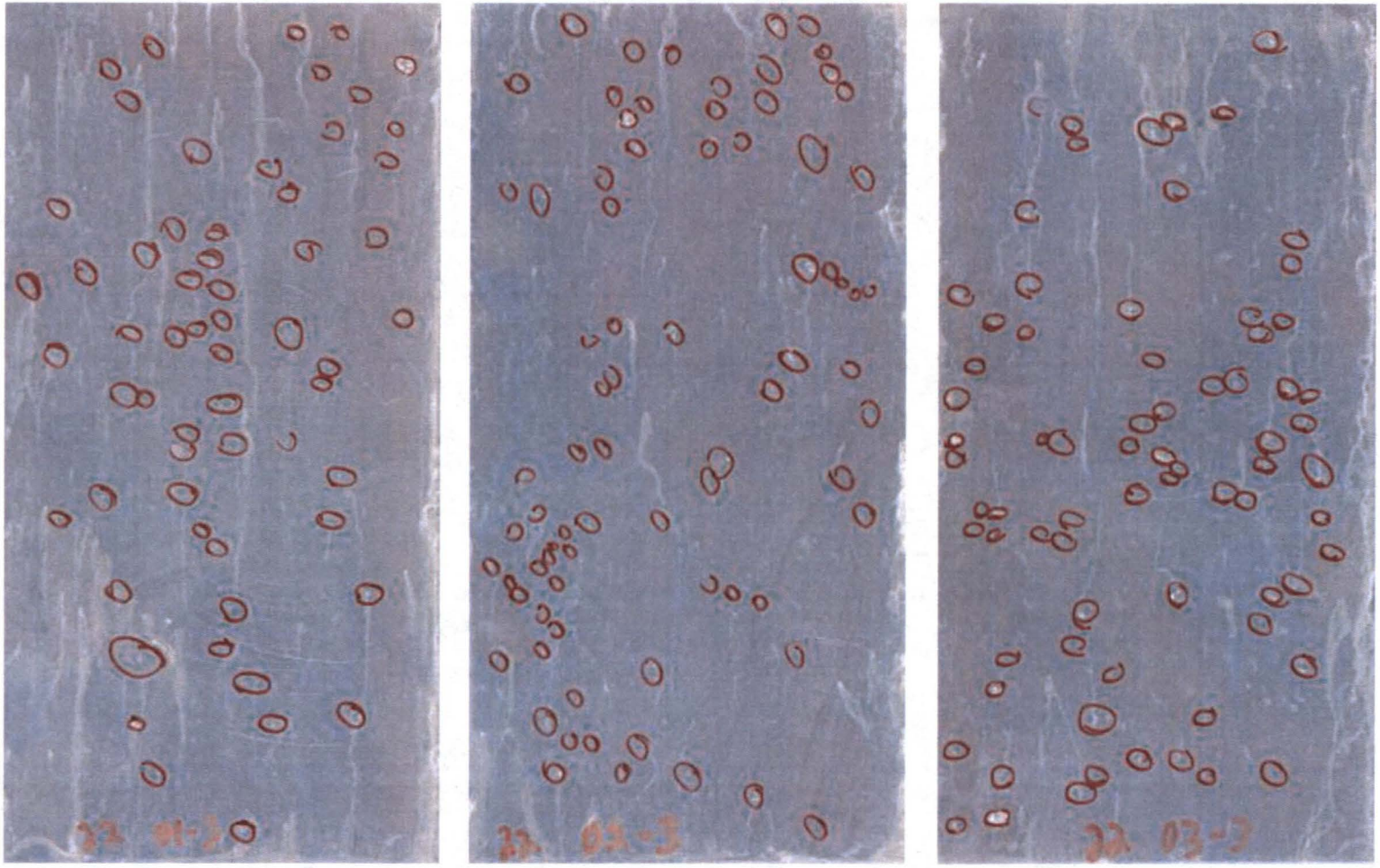
# Metalast HF HPA-100

| 2219 | @ 168 | @ 336 |
|---|---|---|
| MTL 22 01 30 | 27 | 20+ |
| MTL 22 02 30 | 46 | 20+ |
| MTL 22 03 30 | 50+ | 20+ |



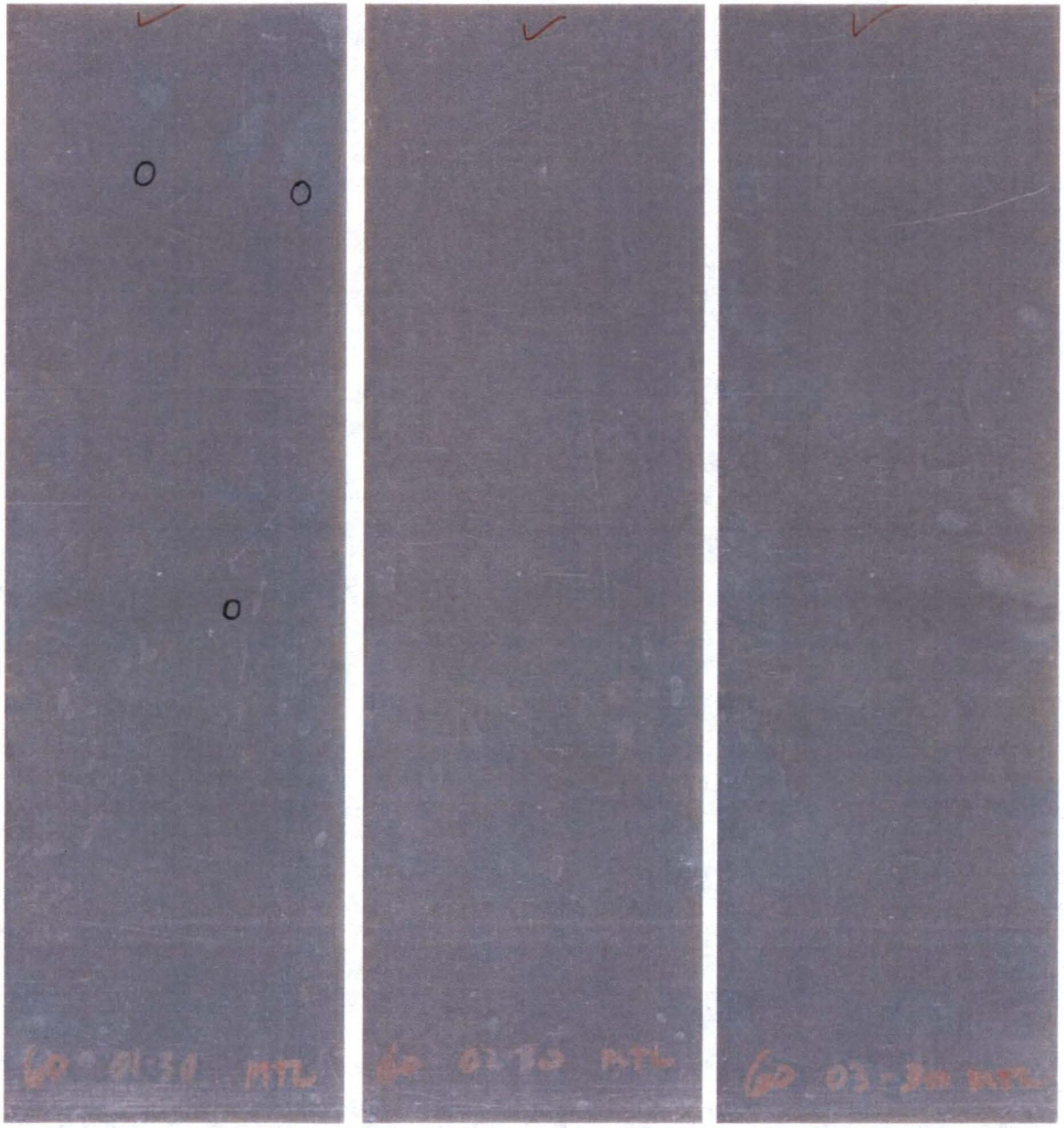
# Metalast HF HPA-100

| 2219 | @ 168 | @ 336 |
|---|---|---|
| MTL 22 01 3 | 50+ | 50+ |
| MTL 22 02 3 | 50+ | 50+ |
| MTL 22 03 3 | 50+ | 50+ |



# Metalast HF HPA-100

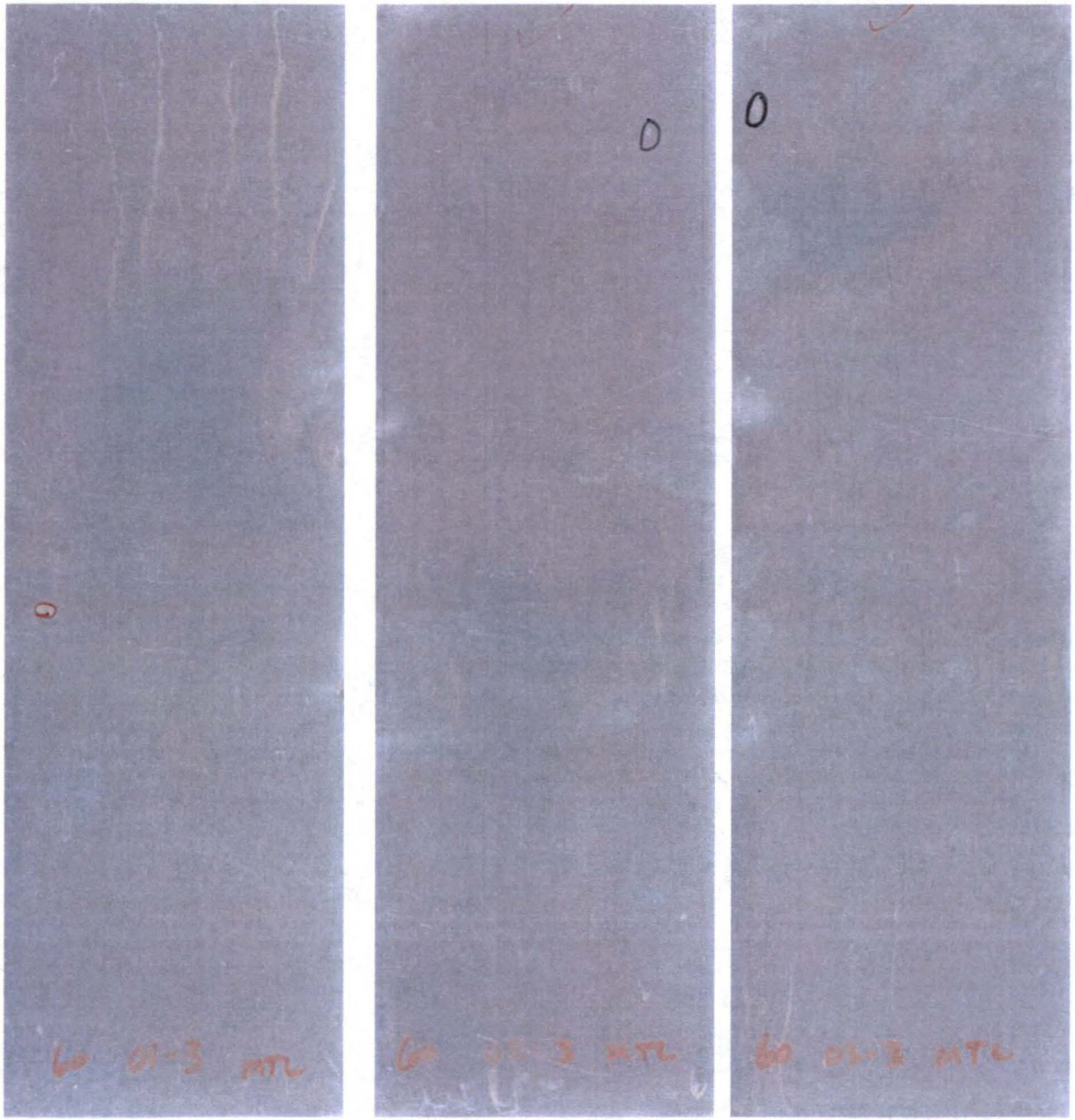
| 6061-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MTL 60 01 30 | 0 | 0 | 0 | 0 |
| MTL 60 02 30 | 0 | 0 | 0 | 0 |
| MTL 60 03 30 | 0 | 0 | 0 | 3 |



# Metalast HF HPA-100

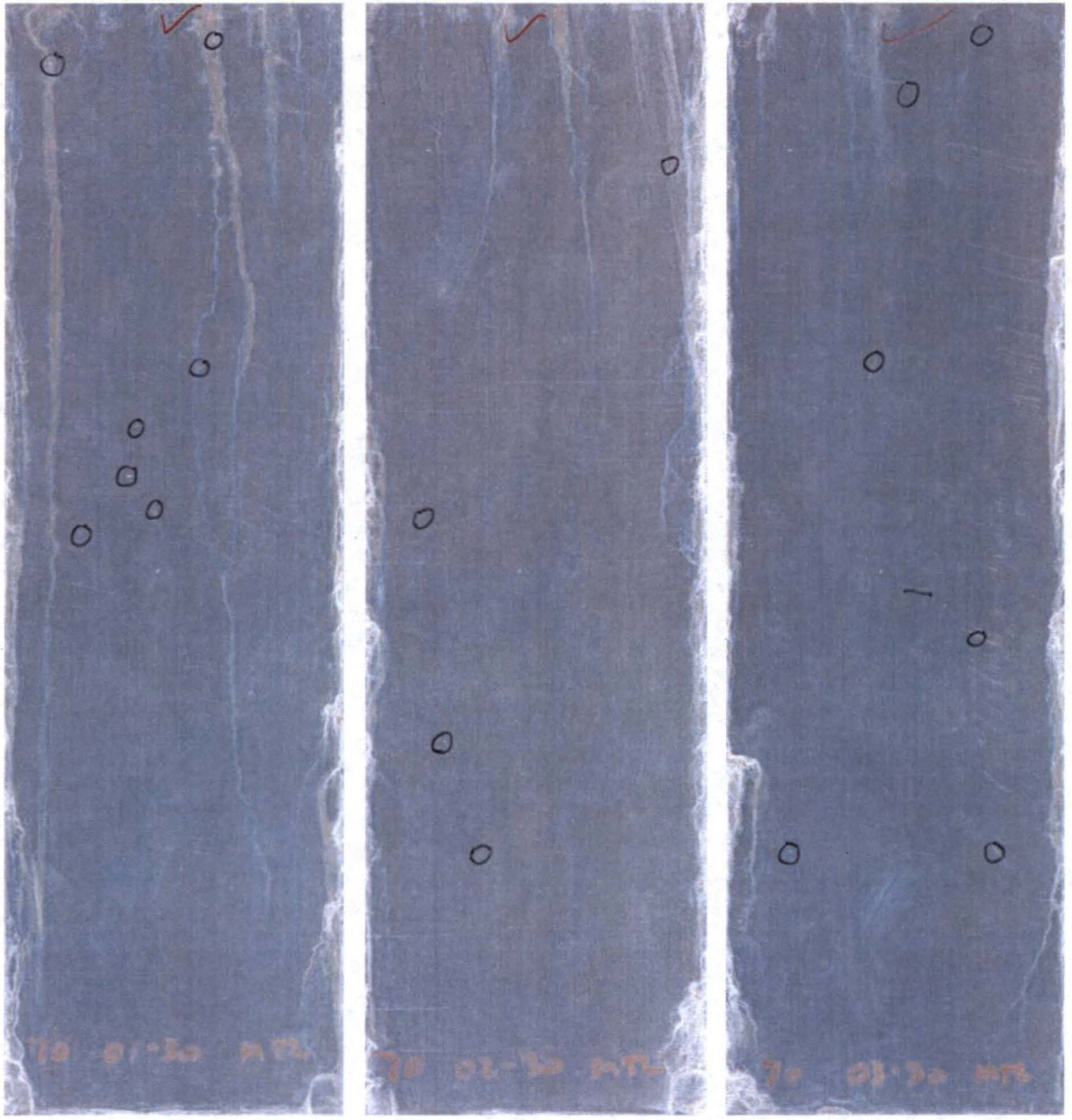
| 6061-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MTL 60 01 3 | 1 | 0 | 0 | * |
| MTL 60 02 3 | 0 | 0 | 1 | 0 |
| MTL 60 03 3 | 0 | 0 | 0 | 0 |

* large area of corrosion, many small pits



# Metalast HF HPA-100

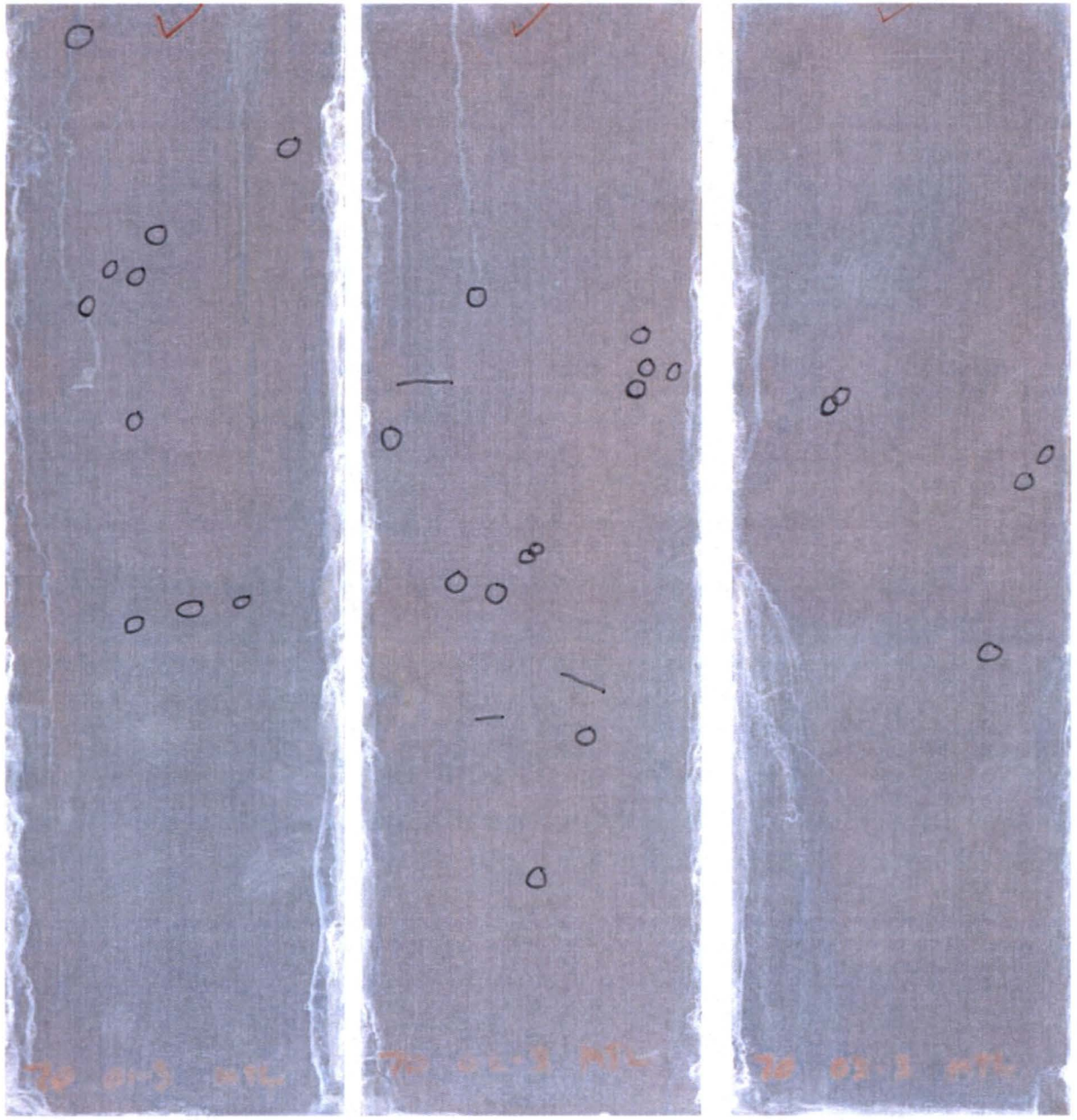
| 7075-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MTL 70 01 30 | 0 | 0 | 0 | 7 |
| MTL 70 02 30 | 0 | 0 | 0 | 4 |
| MTL 70 03 30 | 0 | 0 | 0 | * |
| * pits primarily found in scratches | | | | |



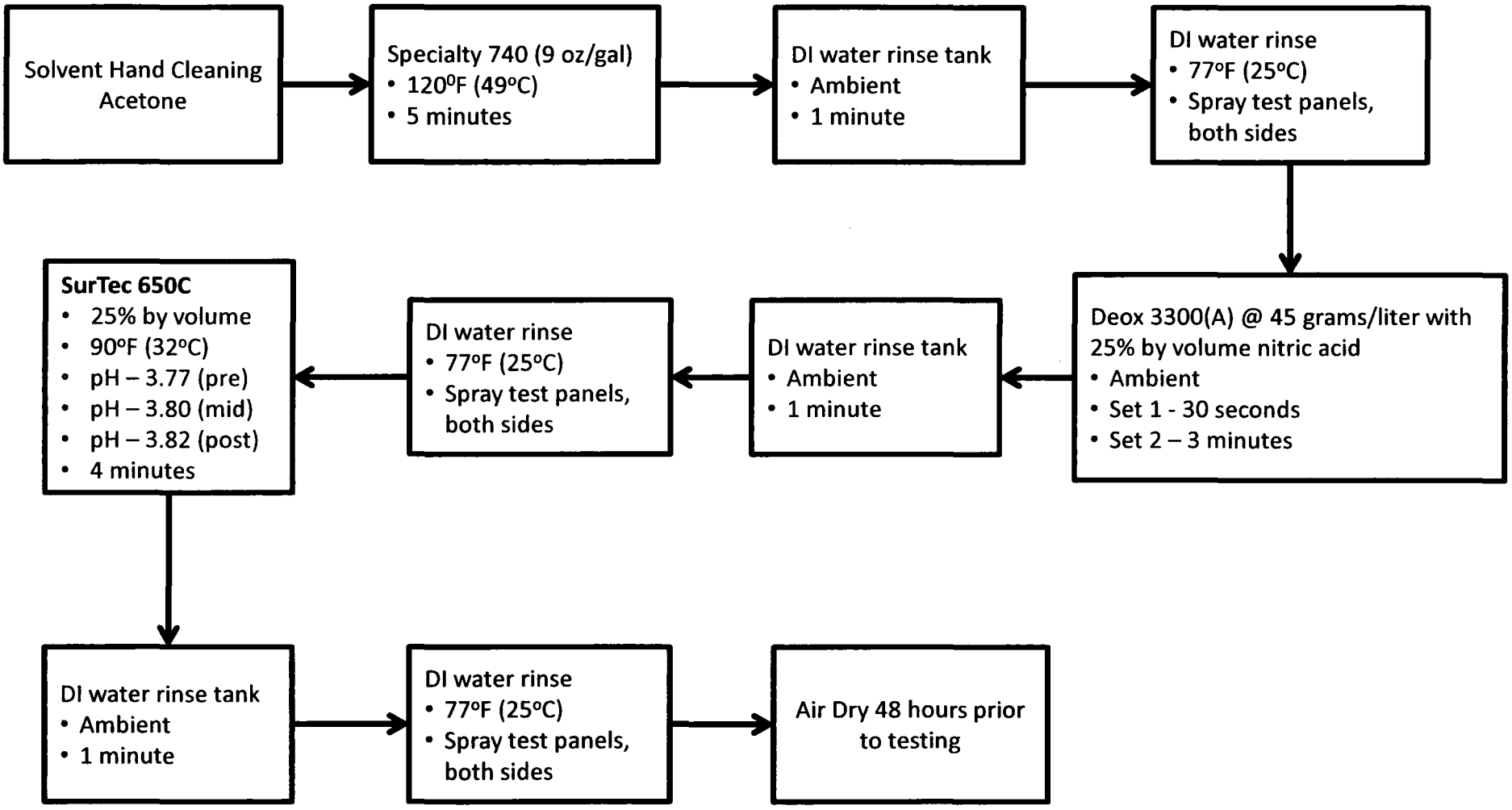
# Metalast HF HPA-100

| 7075-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MTL 70 01 3 | 0 | 0 | 0 | * |
| MTL 70 02 3 | 0 | 0 | 0 | * |
| MTL 70 03 3 | 0 | 0 | 0 | * |

* pits primarily found in scratches



# Pretreatment Process: SurTec 650C



# SurTec 650C

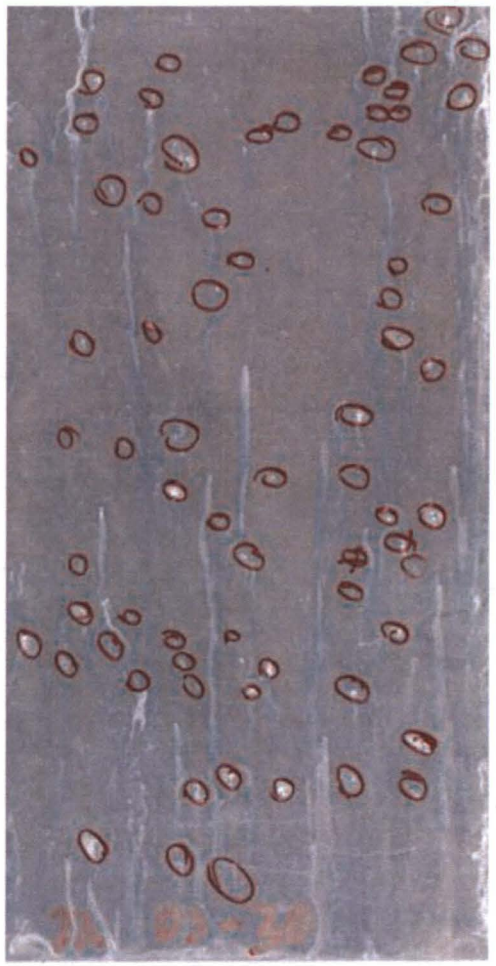
| 2024-T3 | @ 168 | @ 336 |
|---|---|---|
| SRT 20 01 30 | 22 | 20+ |
| SRT 20 02 30 | 50+ | 20+ |
| SRT 20 03 30 | 30 | 20+ |

# SurTec 650C

| 2024-T3 | @ 168 | @ 336 |
|---|---|---|
| SRT 20 01 3 | 50+ | 20+ |
| SRT 20 02 3 | 50+ | 20+ |
| SRT 20 03 3 | 50+ | 20+ |

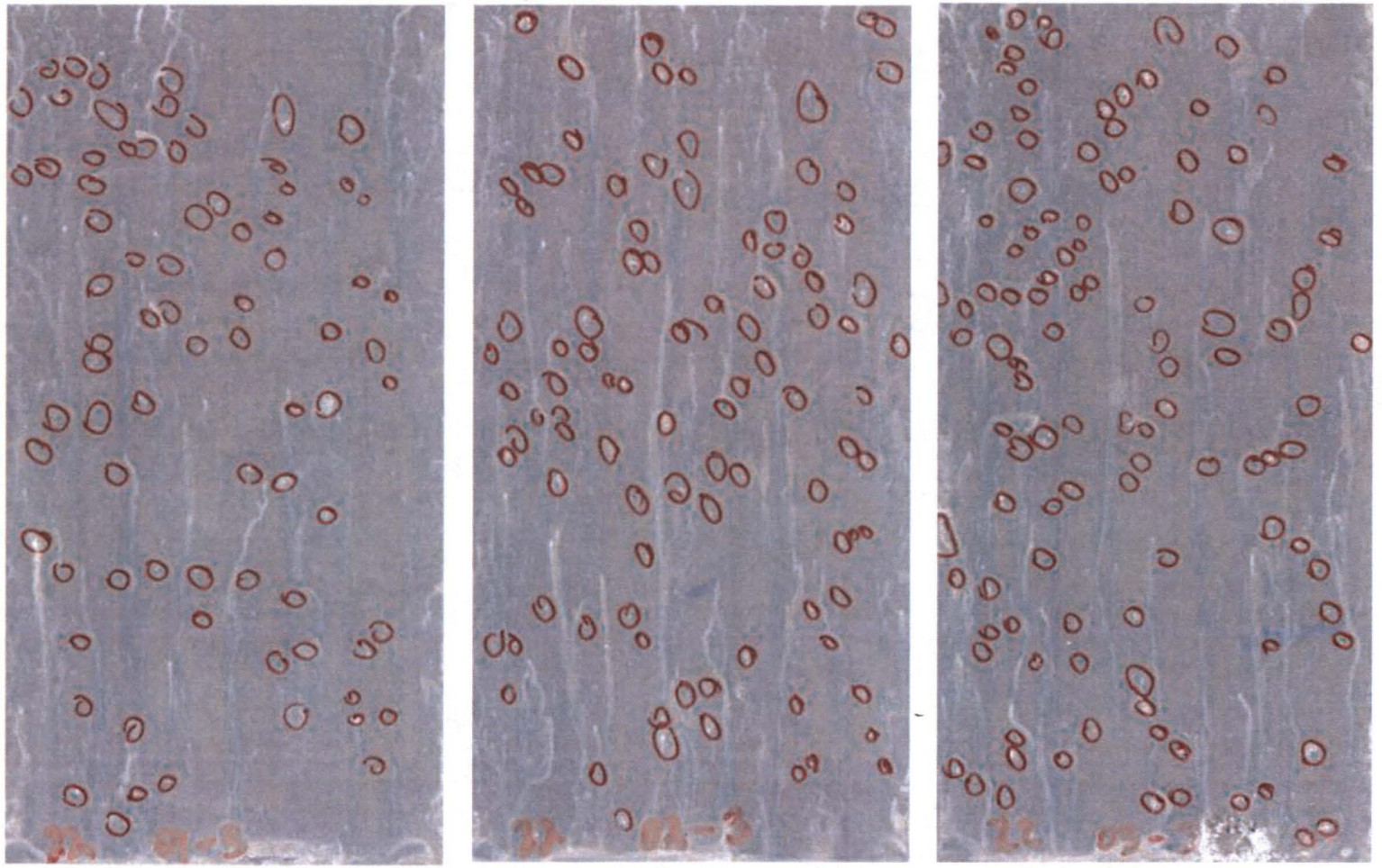
SurTec 650C

| 2219 | @ 168 | @ 336 |
|---|---|---|
| SRT 22 01 30 | 50+ | 20+ |
| SRT 22 02 30 | 50+ | 20+ |
| SRT 22 03 30 | 50+ | 20+ |



SurTec 650C

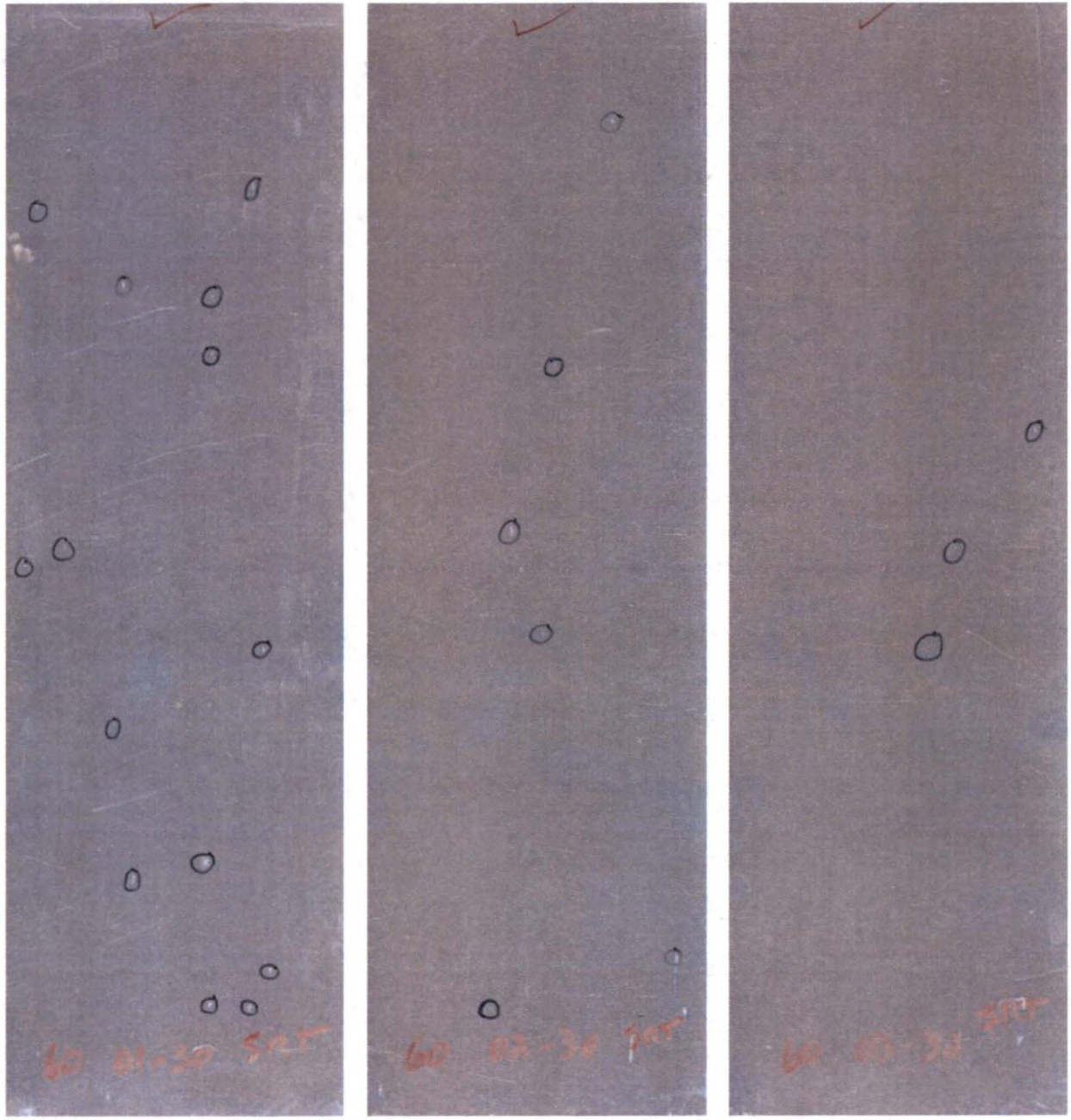
| 2219 | @ 168 | @ 336 |
|---|---|---|
| SRT 22 01 3 | 50+ | 20+ |
| SRT 22 02 3 | 50+ | 20+ |
| SRT 22 03 3 | 50+ | 20+ |



# SurTec 650C

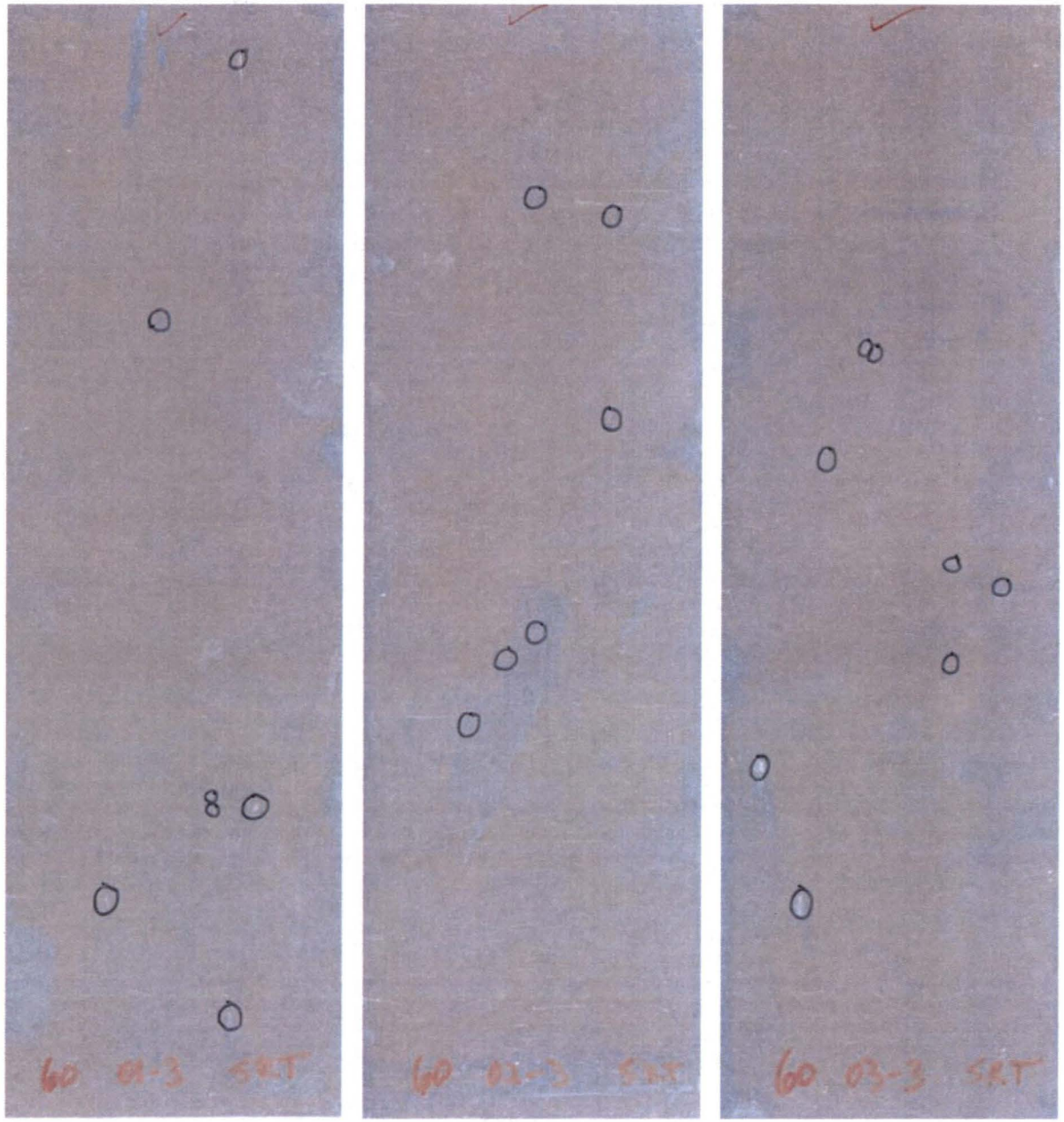
| 6061-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| SRT 60 01 30 | 0 | 0 | 6 | *10+ |
| SRT 60 02 30 | 0 | 0 | 3 | 2 |
| SRT 60 03 30 | 0 | 0 | 2 | 1 |

* numerous small pits observed



# SurTec 650C

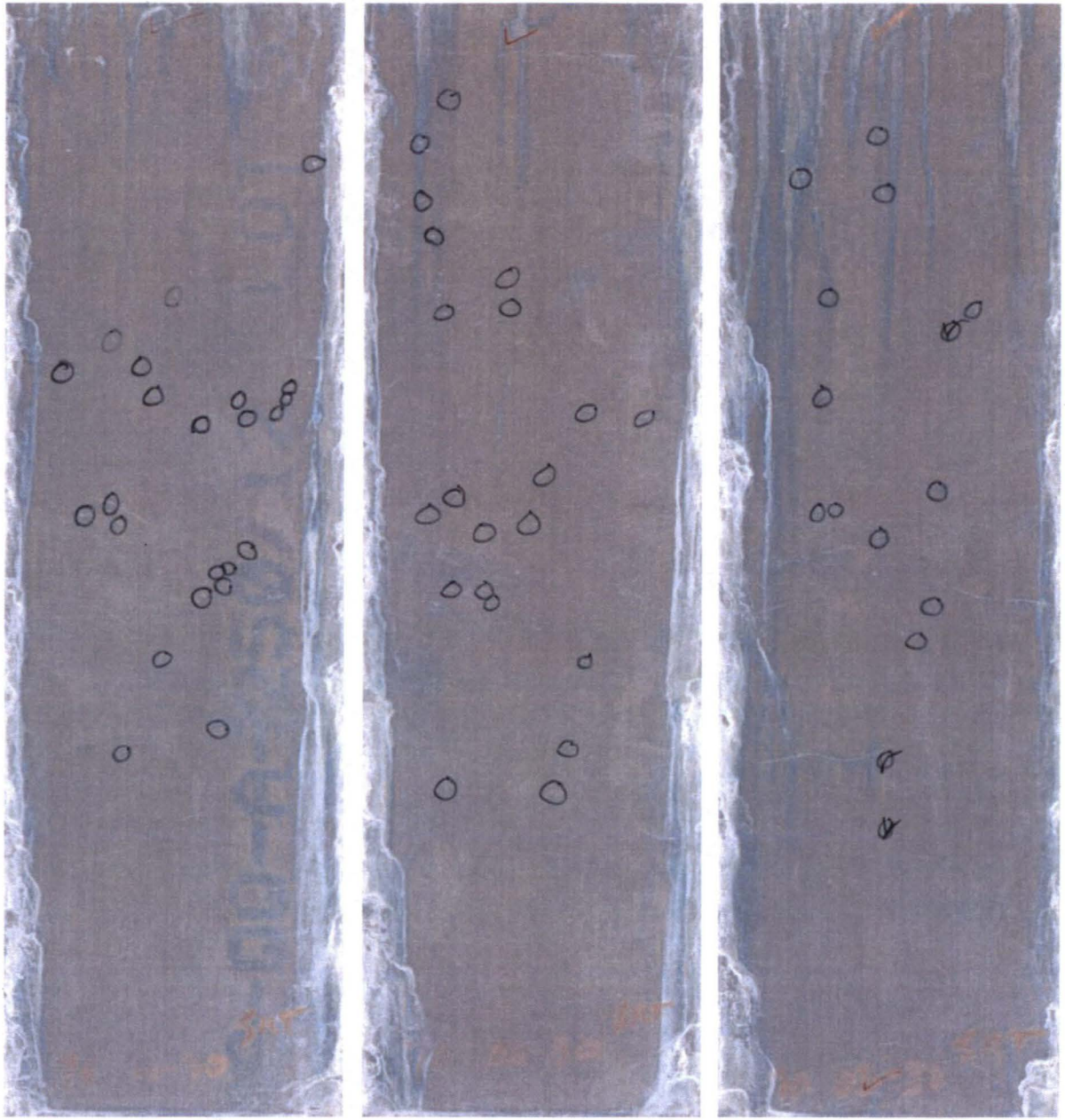
| 6061-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| SRT 60 01 3 | 0 | 0 | 0 | 7 |
| SRT 60 02 3 | 0 | 0 | 0 | 8 |
| SRT 60 03 3 | 0 | 0 | 1 | *5+ |
| * large corrosion spots observed | | | | |



# SurTec 650C

| 7075-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| SRT 70 01 30 | 0 | 0 | 4 | *10+ |
| SRT 70 02 30 | 0 | 0 | 0 | *10+ |
| SRT 70 03 30 | 0 | 0 | 0 | *10+ |

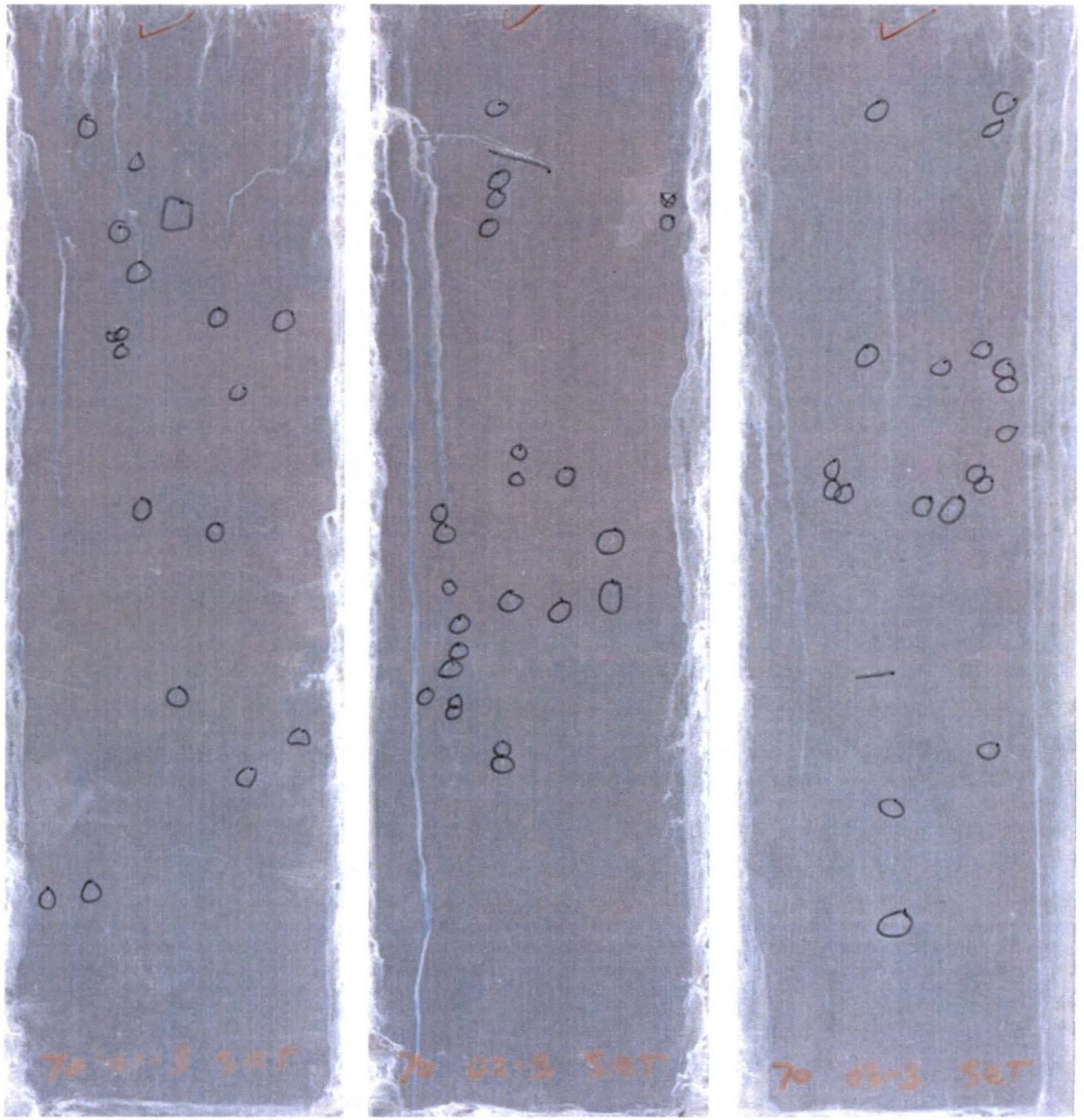
* numerous small pits, several associated with scratches



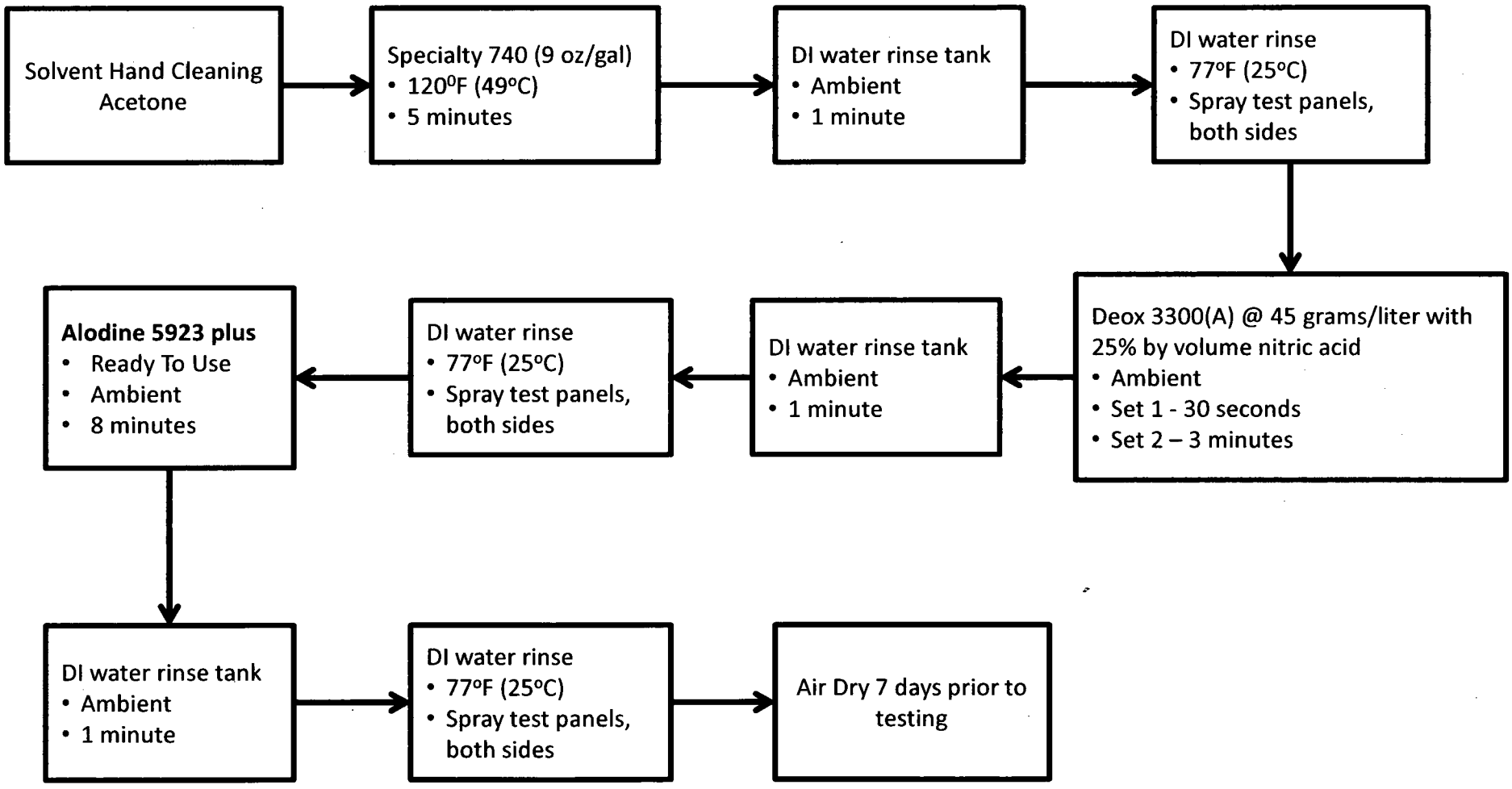
# SurTec 650C

| 7075-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| SRT 70 01 3 | 0 | 0 | 0 | *10+ |
| SRT 70 02 3 | 0 | 0 | 2 | *10+ |
| SRT 70 03 3 | 0 | 0 | 0 | *10+ |

* numerous small pits, several associated with scratches

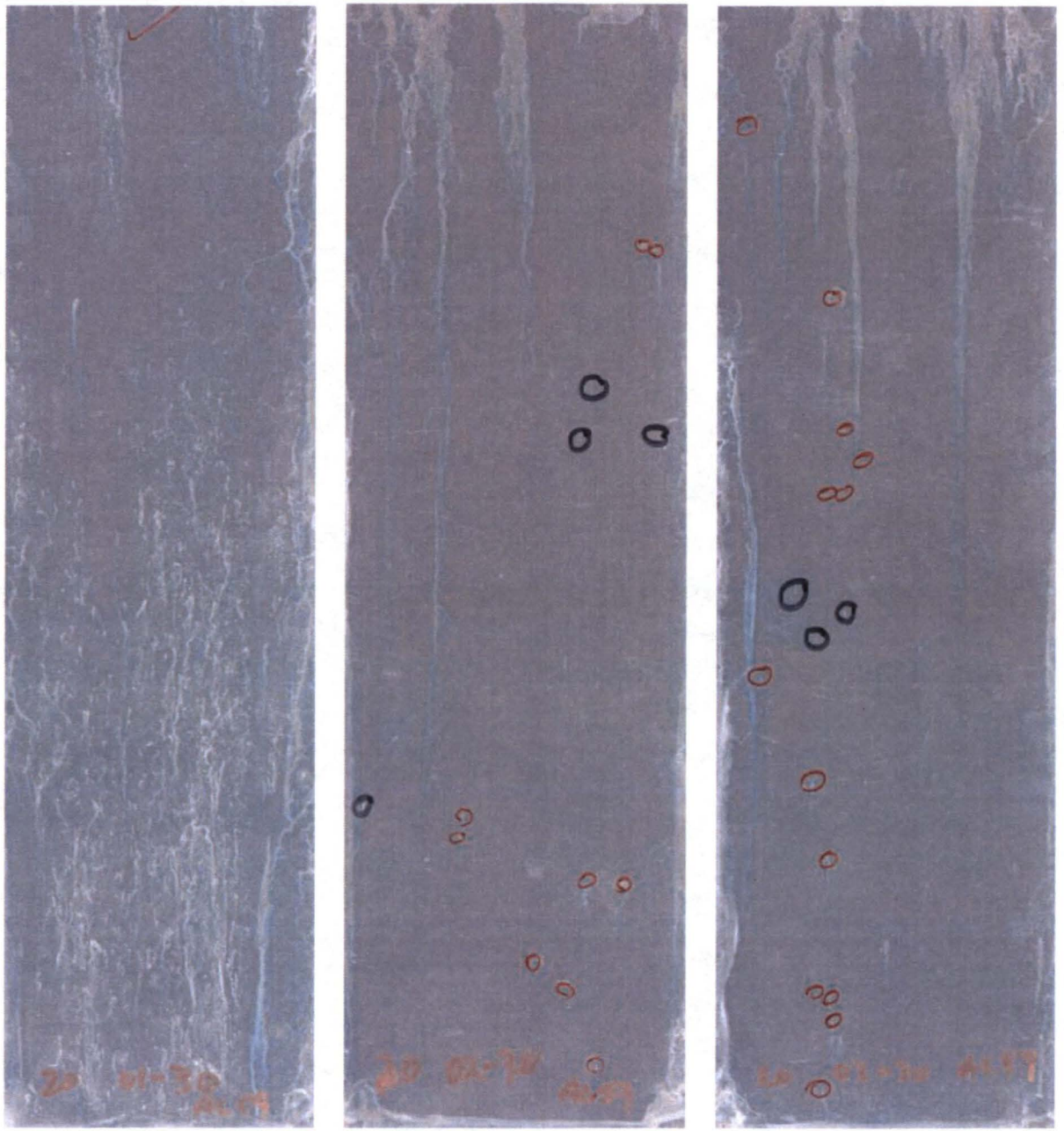


# Pretreatment Process: Alodine 5923 plus



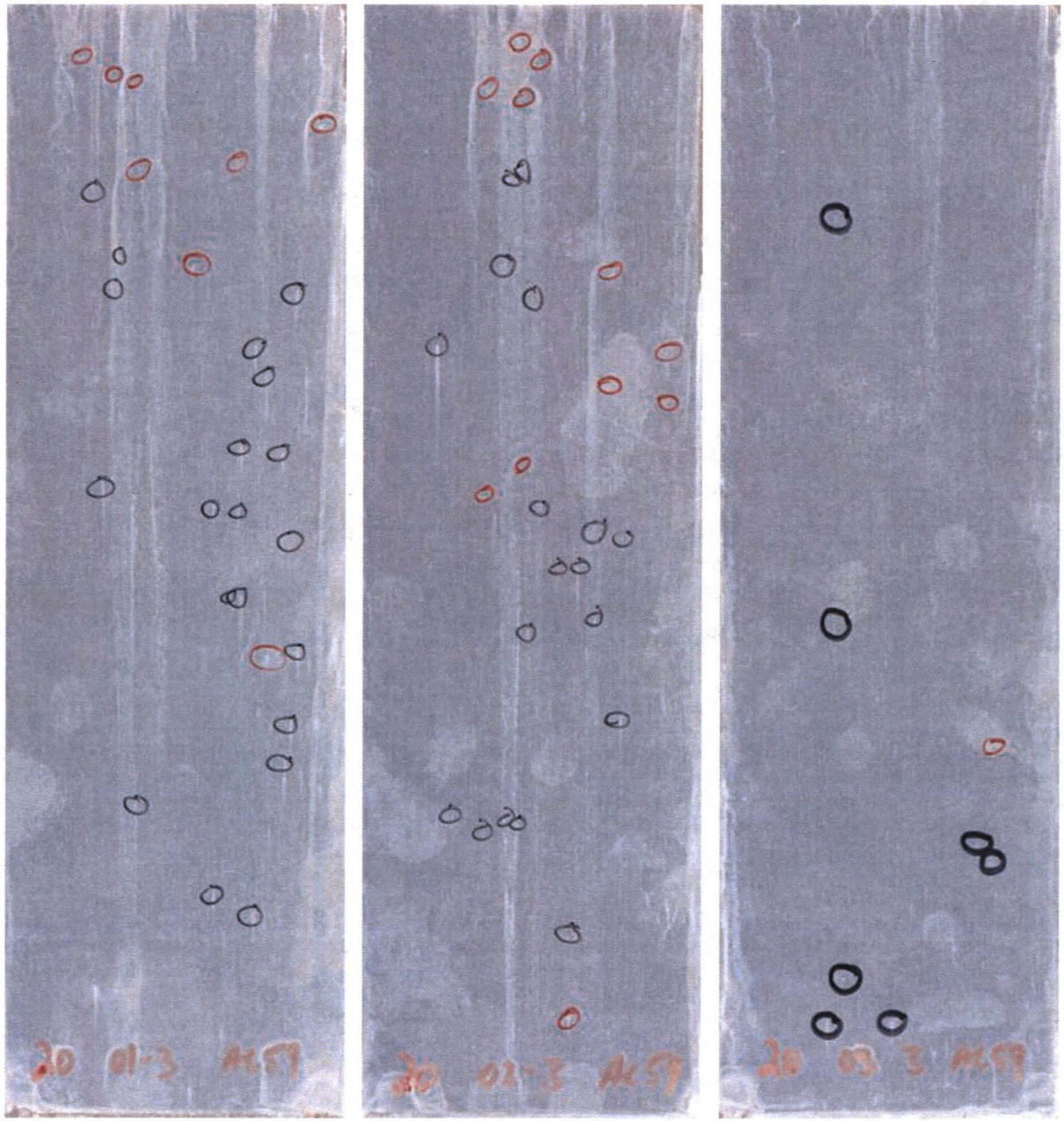
# Alodine 5923 Plus

| 2024-T3 | @ 168 | @ 336 | @ 504 |
|---|---|---|---|
| AL59 20 01 30 | 0 | 0 | 20+ |
| AL59 20 02 30 | 9 | 4 | |
| AL59 20 03 30 | 13 | 3 | |



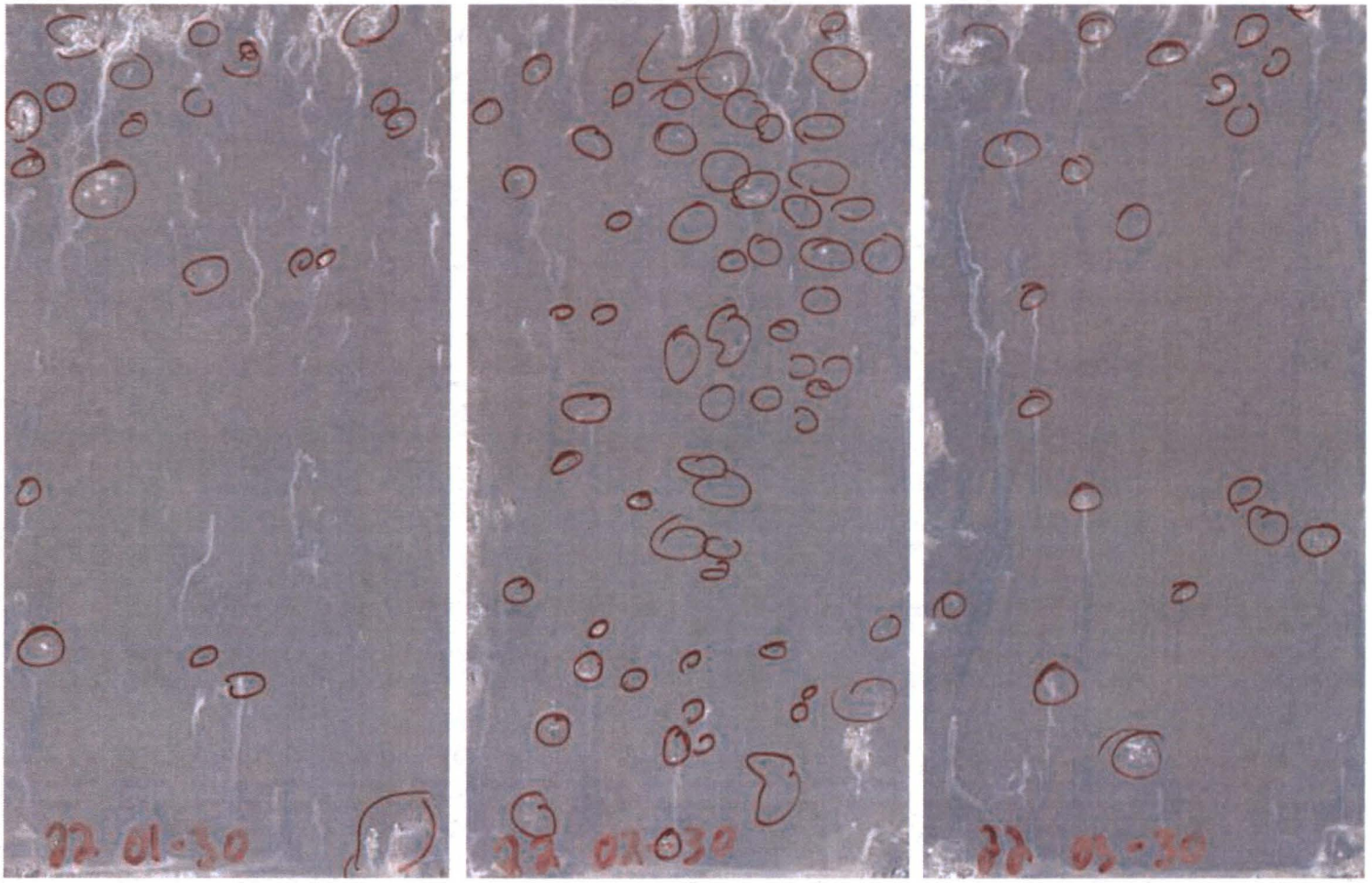
# Alodine 5923 Plus

| 2024-T3 | @ 168 | @ 336 |
|---|---|---|
| AL59 20 01 3 | 8 | 20+ |
| AL59 20 02 3 | 11 | 20+ |
| AL59 20 03 3 | 1 | 7 |



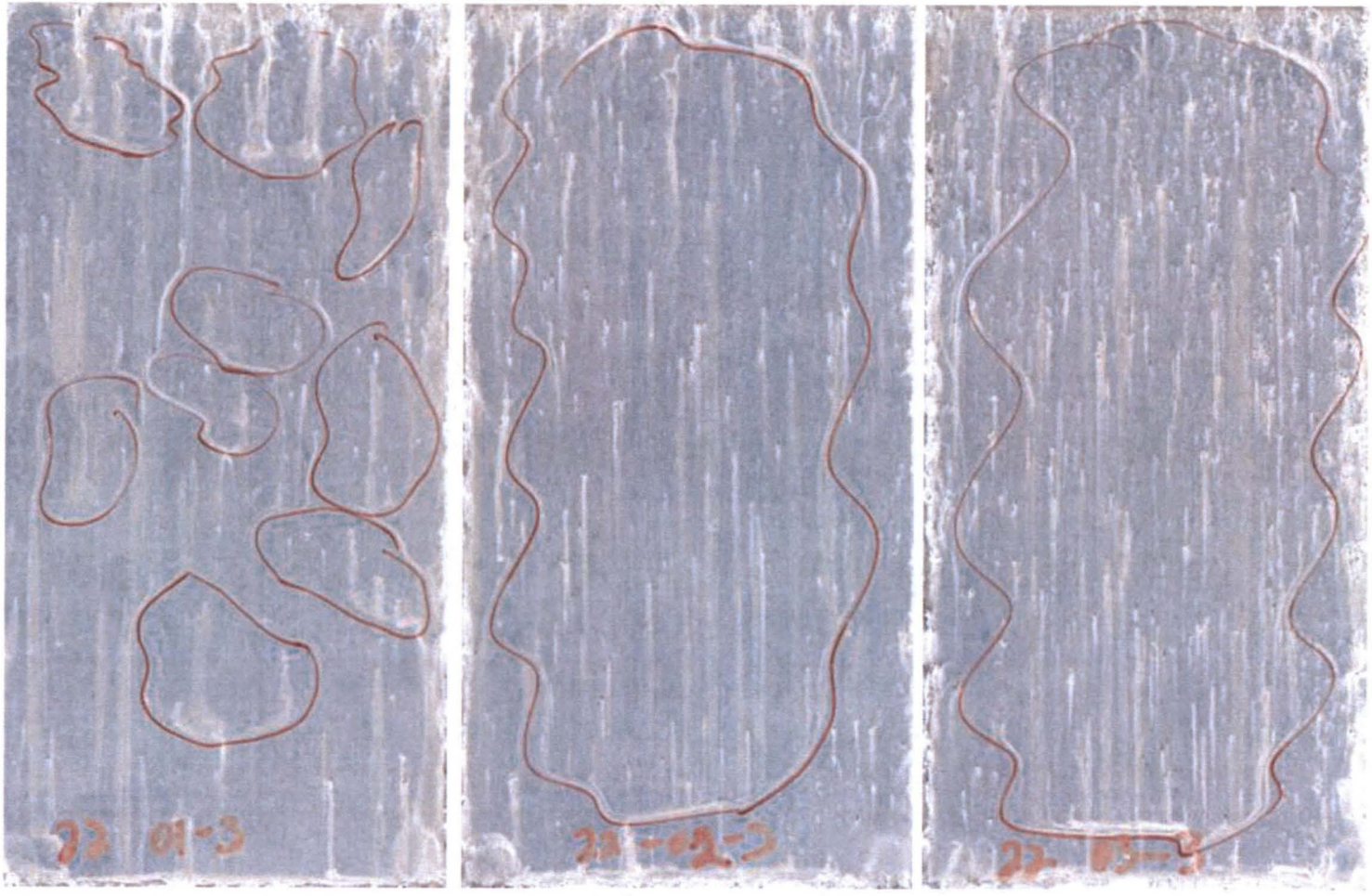
Alodine 5923 Plus

| 2219 | @ 168 | @ 336 |
|---|---|---|
| AL59 22 01 30 | 22 | 20+ |
| AL59 22 02 30 | 50+ | 20+ |
| AL59 22 03 30 | 19 | 20+ |



Alodine 5923 Plus

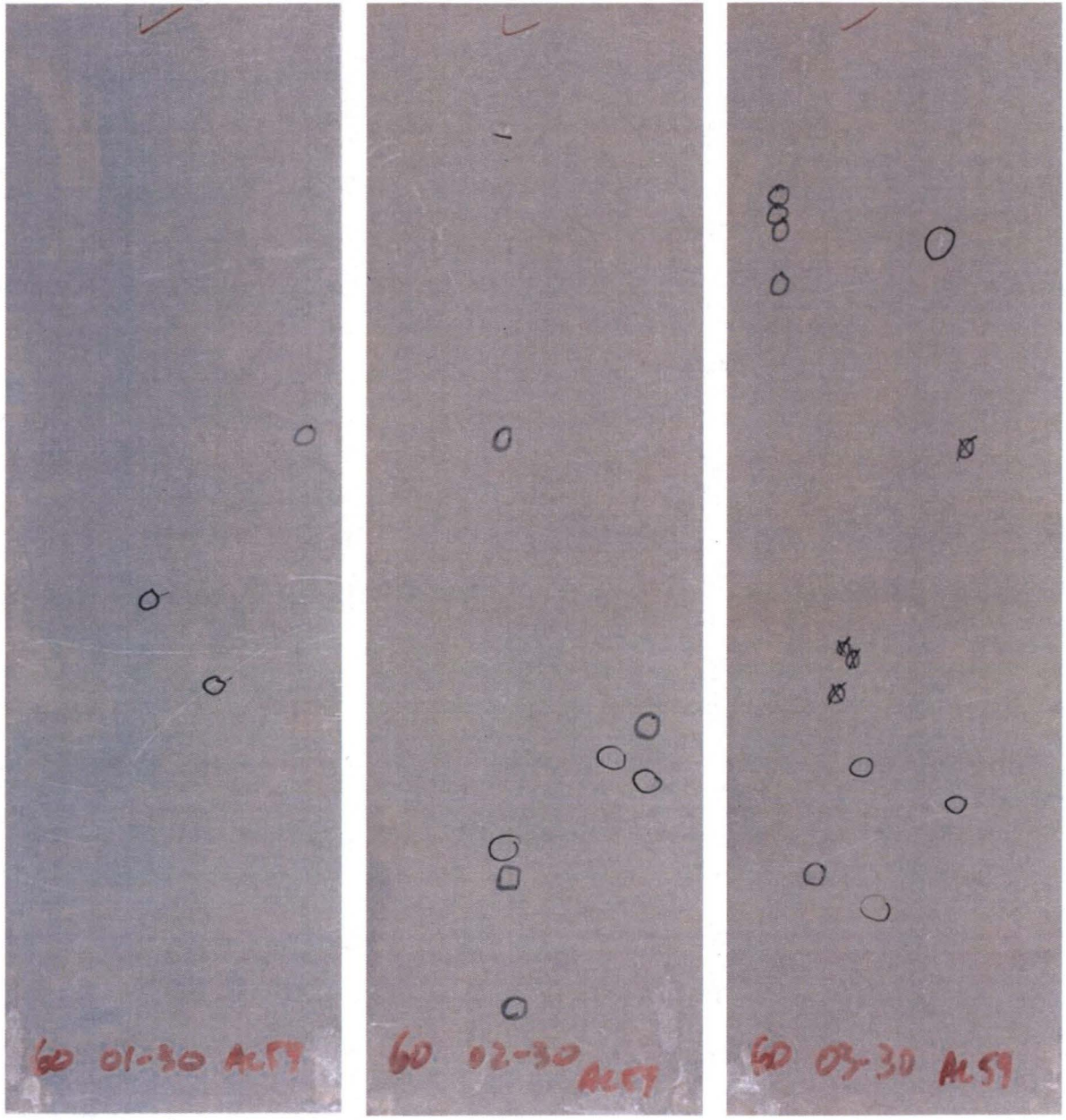
| 2219 | @ 168 | @ 336 |
|---|---|---|
| AL59 22 01 3 | 50+ | 50+ |
| AL59 22 02 3 | 50+ | 50+ |
| AL59 22 03 3 | 50+ | 50+ |



# Alodine 5923 Plus

| 6061-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL59 60 01 30 | 0 | 0 | 0 | 3* |
| AL59 60 02 30 | 0 | 0 | 0 | 5+ |
| AL59 60 03 30 | 0 | 0 | 0 | 5+ |

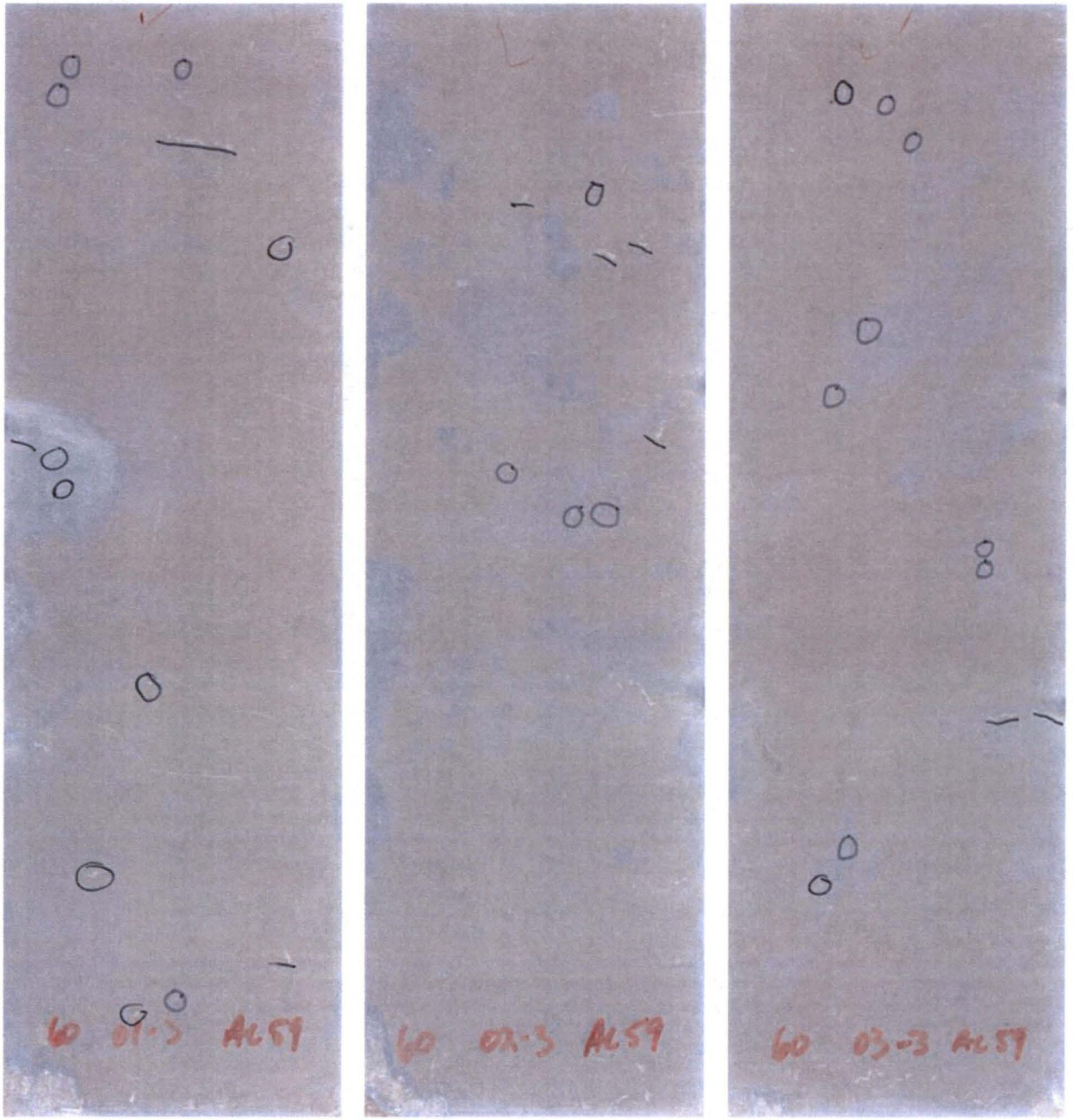
* signs of corrosion associated with scratches



# Alodine 5923 Plus

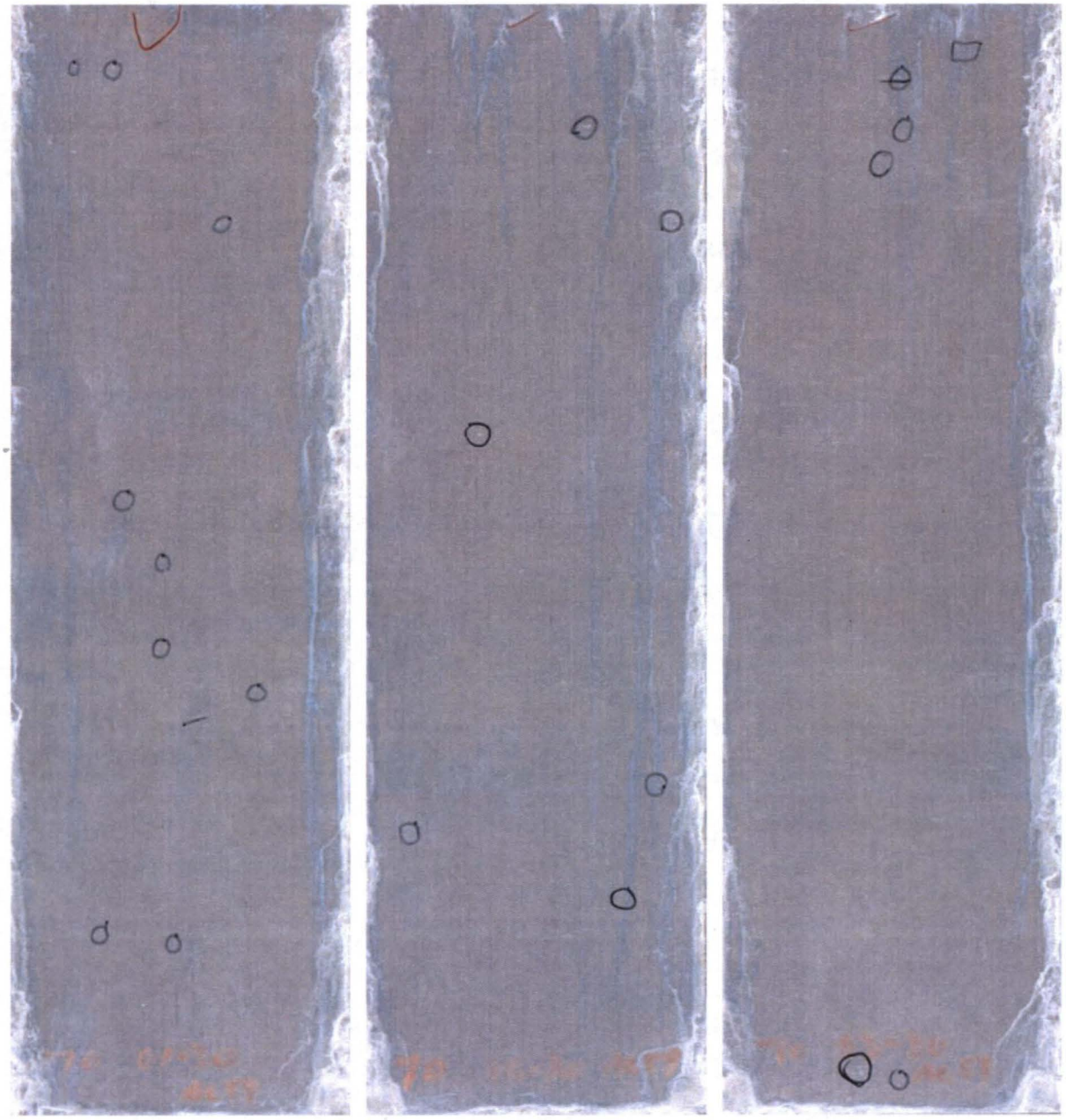
| 6061-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL59 60 01 3 | 0 | 0 | 0 | 5+ |
| AL59 60 02 3 | 0 | 0 | 0 | 4* |
| AL59 60 03 3 | 0 | 0 | 0 | 5+ |

* spots and blobs may be signs of multiple small pits



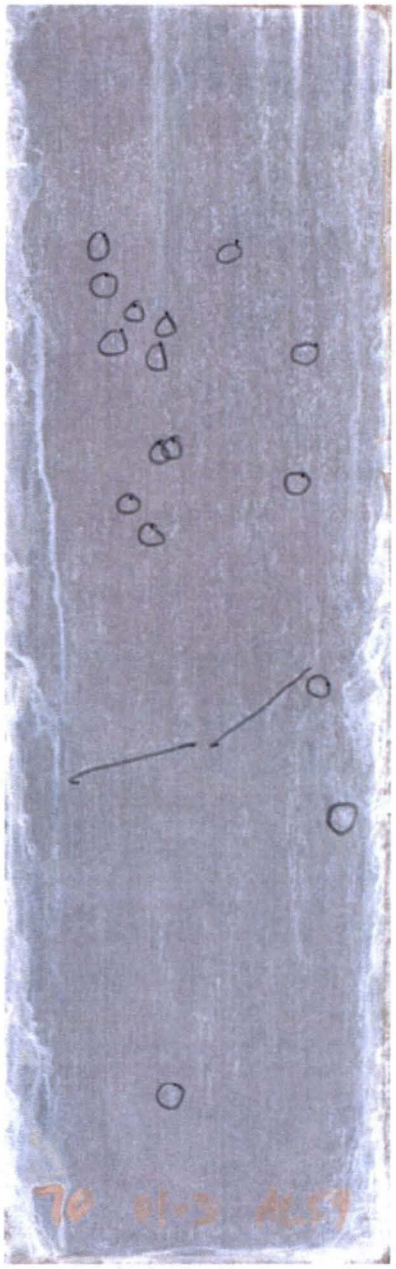
# Alodine 5923 Plus

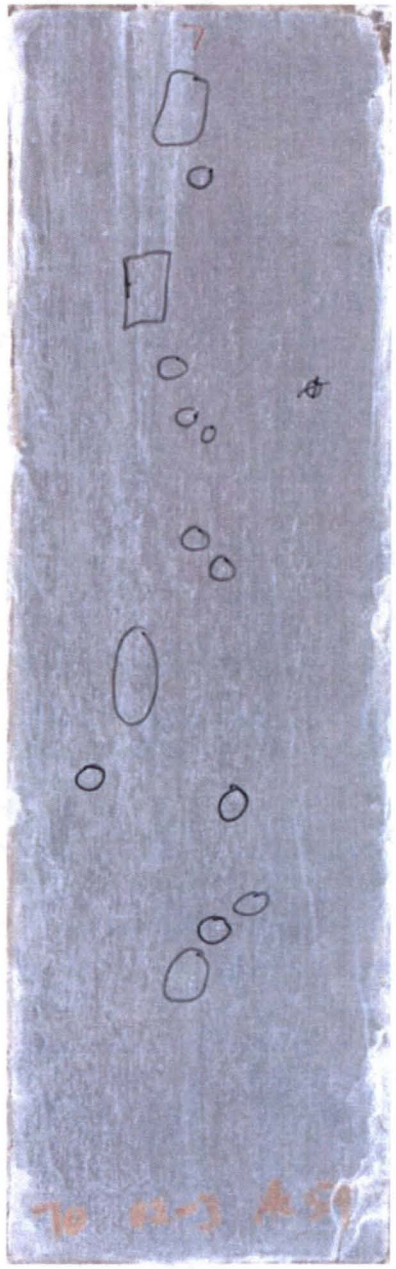
| 7075-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL59 70 01 30 | 0 | 0 | 0 | *5+ |
| AL59 70 02 30 | 0 | 0 | 0 | *5+ |
| AL59 70 03 30 | 0 | 0 | 0 | 5 |
| * some pits found in scratches | | | | |
| ** numerous small pits | | | | |

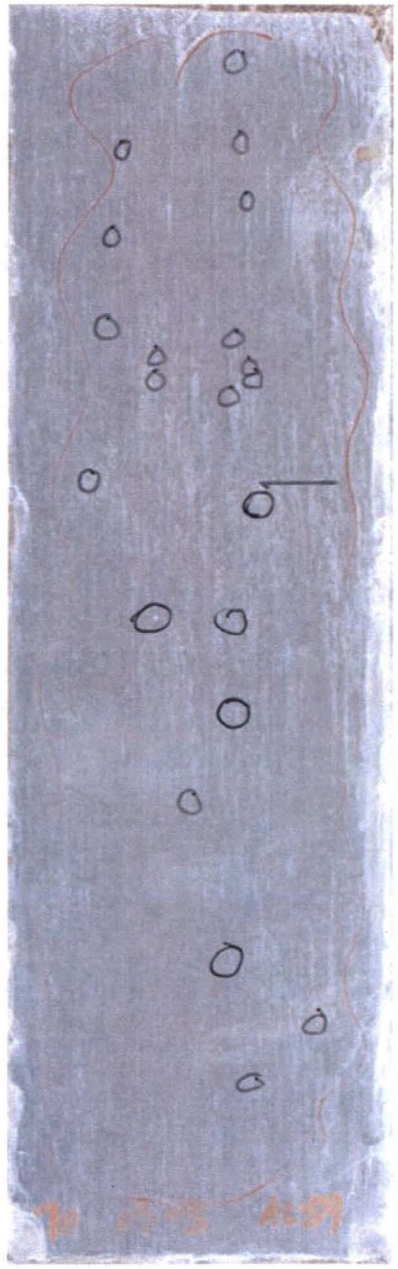


# Alodine 5923 Plus

| 7075-T6 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL59 70 01 3 | 0 | 0 | 1 | **50+ |
| AL59 70 02 3 | 0 | 0 | 1 | **50+ |
| AL59 70 03 3 | 0 | 0 | 0 | **50+ |
| ** numerous small pits | | | | |



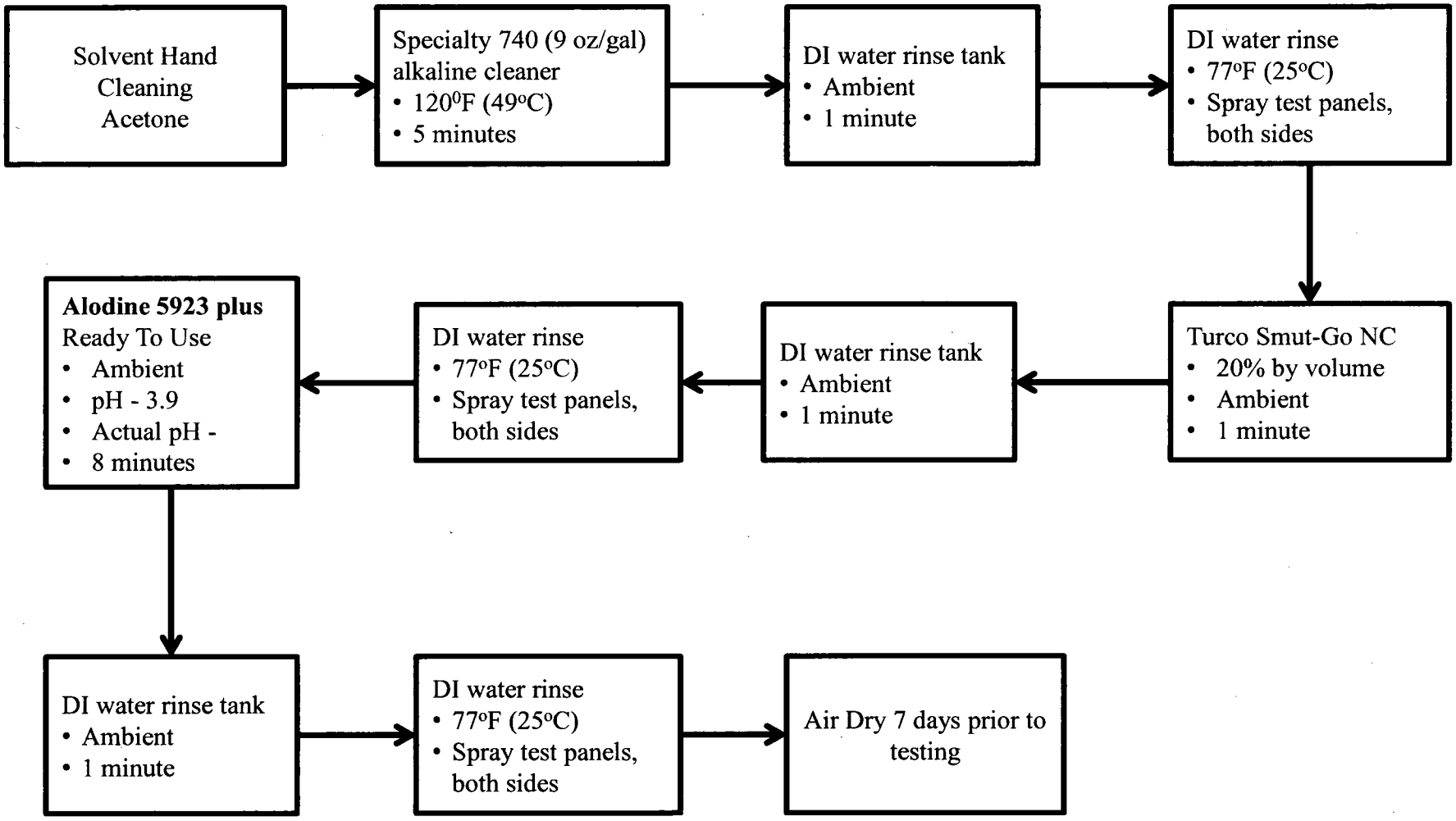




# Test Panel Preparation
# Process Optimization {IV}

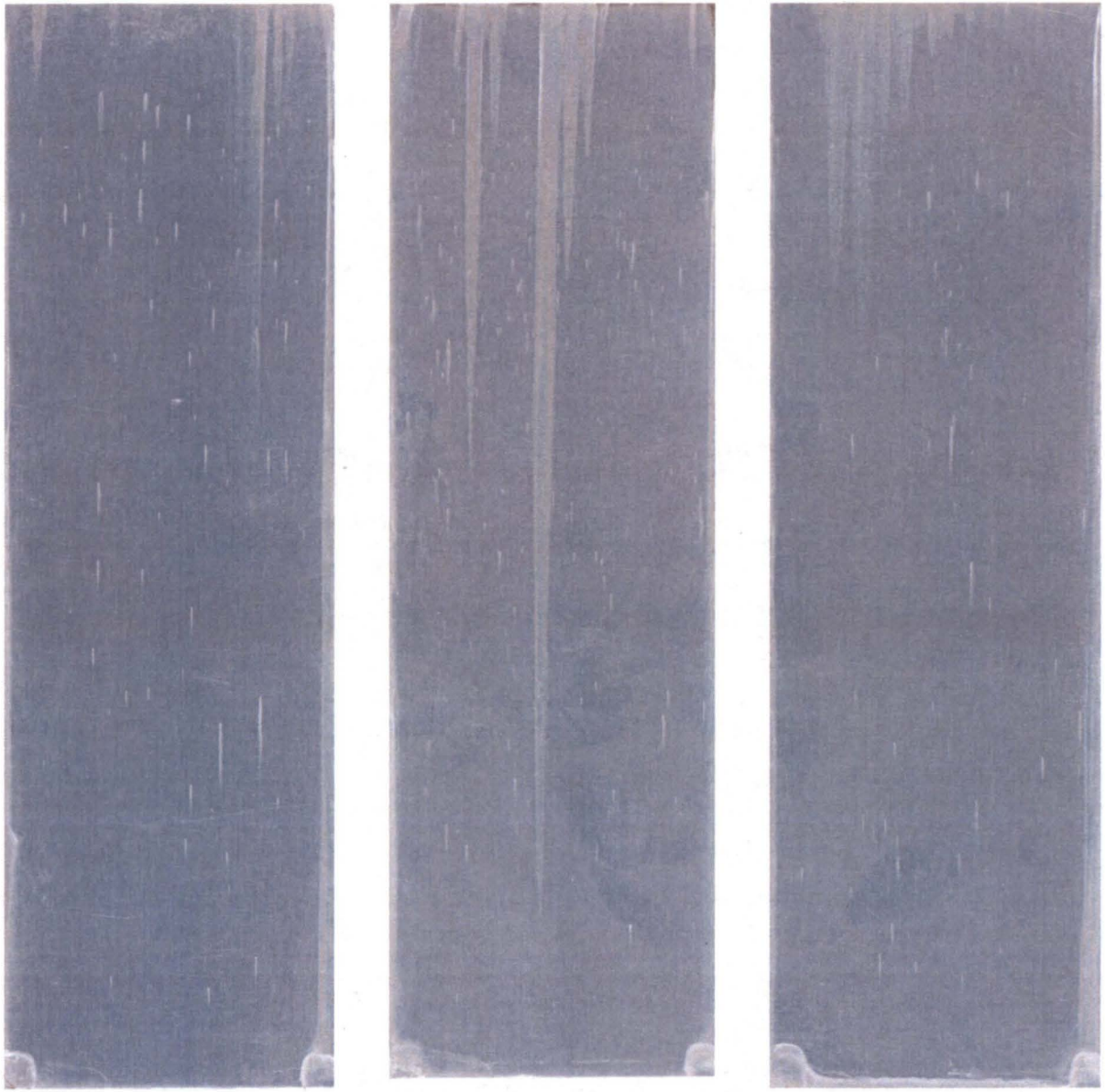
- Changing deoxidizer to Turco Smut-Go NC
- Using SurTec 650V
- Using Alodine 5923 plus, from Henkel Europe

# Pretreatment Process: Alodine 5923 plus



# Alodine 5923 plus

| 2024-T3 | @ 168 |
|---|---|
| AL59 20 01 | 5+ |
| AL59 20 02 | 5+ |
| AL59 20 03 | 5+ |



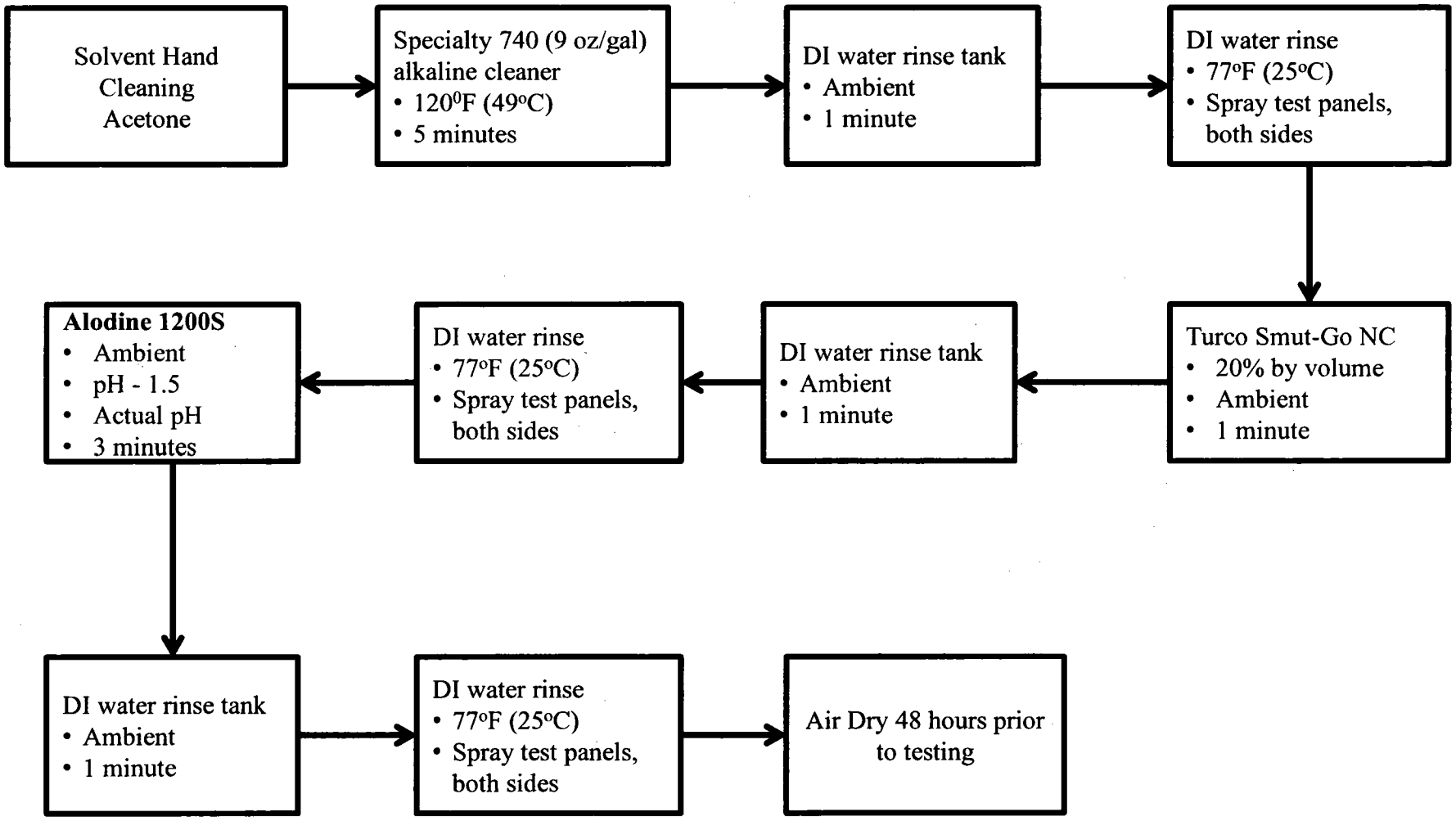
## Alodine 5923 plus

| **5052-H32** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL59 50 01 | 0 | 1 | | |
| AL59 50 02 | 0 | 0 | | |
| AL59 50 03 | 0 | 0 | | |

| **6061-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL59 60 01 | 0 | 0 | | |
| AL59 60 02 | 0 | 0 | | |
| AL59 60 03 | 0 | 0 | | |

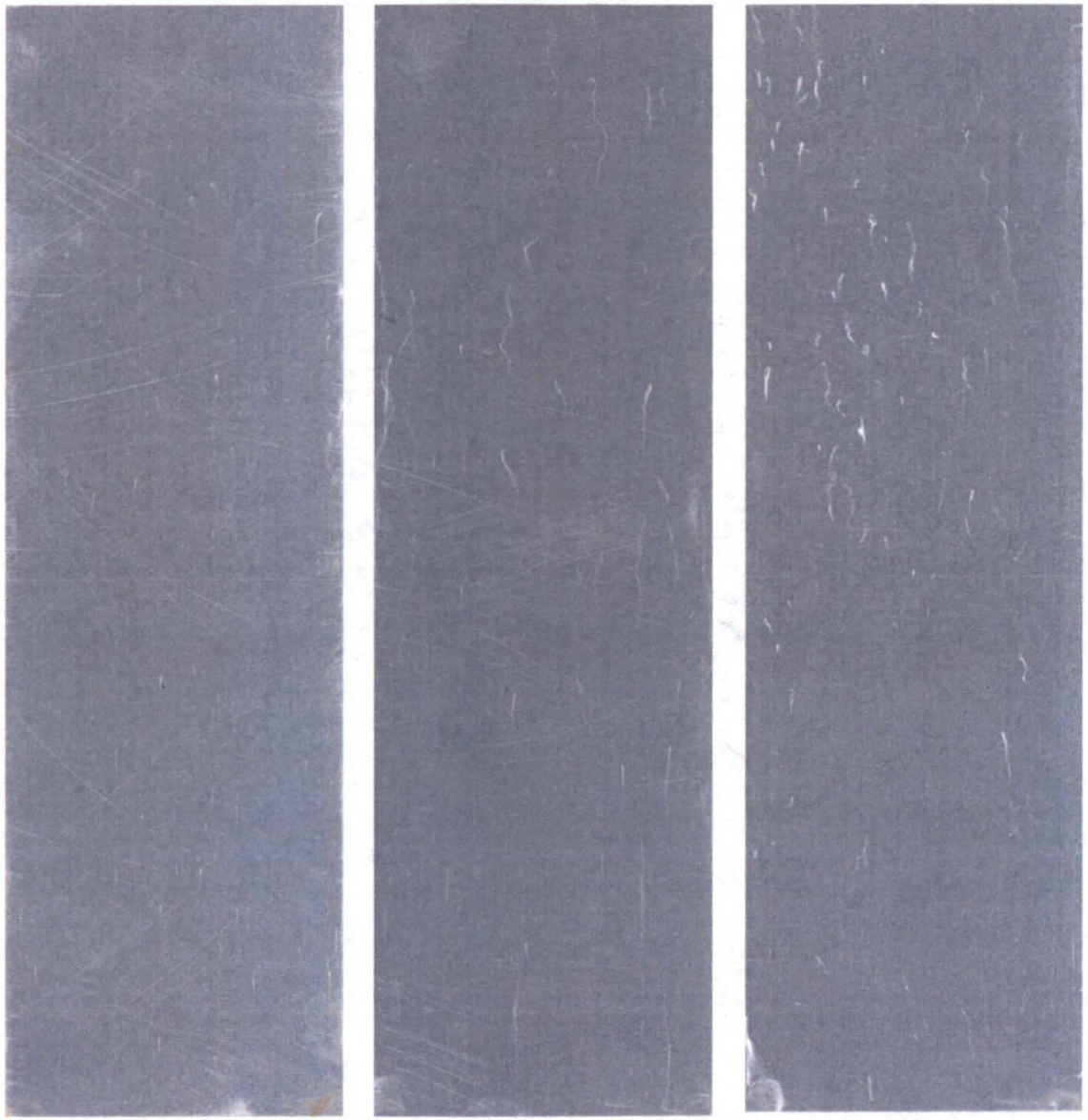
| **7075-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL59 70 01 | 0 | 0 | | |
| AL59 70 02 | 0 | 0 | | |
| AL59 70 03 | 0 | 0 | | |

# Pretreatment Process: Alodine 1200S



# Alodine 1200S

| 2024-T3 | @ 168 |
|---|---|
| AL12 20 01 | 5+ |
| AL12 20 02 | 5+ |
| AL12 20 03 | 5+ |



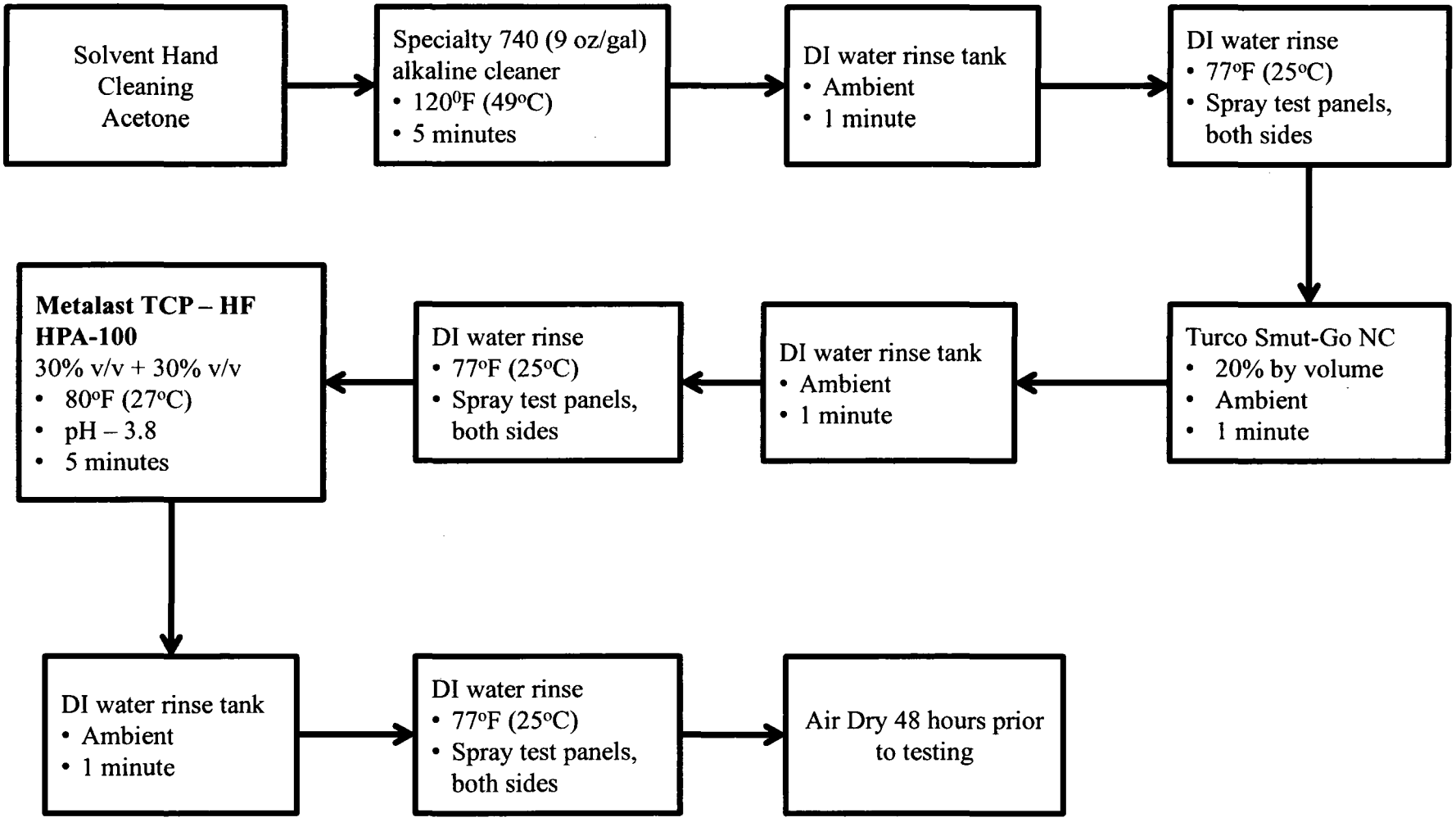
# Alodine 1200S

| **5052-H32** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL12 50 01 | 0 | 0 | | |
| AL12 50 02 | 0 | 0 | | |
| AL12 50 03 | 0 | 0 | | |

| **6061-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL12 60 01 | 0 | 0 | | |
| AL12 60 02 | 0 | 0 | | |
| AL12 60 03 | 0 | 0 | | |

| **7075-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL12 70 01 | 0 | 0 | | |
| AL12 70 02 | 0 | 0 | | |
| AL12 70 03 | 0 | 0 | | |

# Pretreatment Process: Metalast TCP HF HPA 100



# Metalast TCP HF HPA 100

| 2024-T3 | @ 168 |
|---|---|
| MT 20 01 | 5+ |
| MT 20 02 | 5+ |
| MT 20 03 | 5+ |

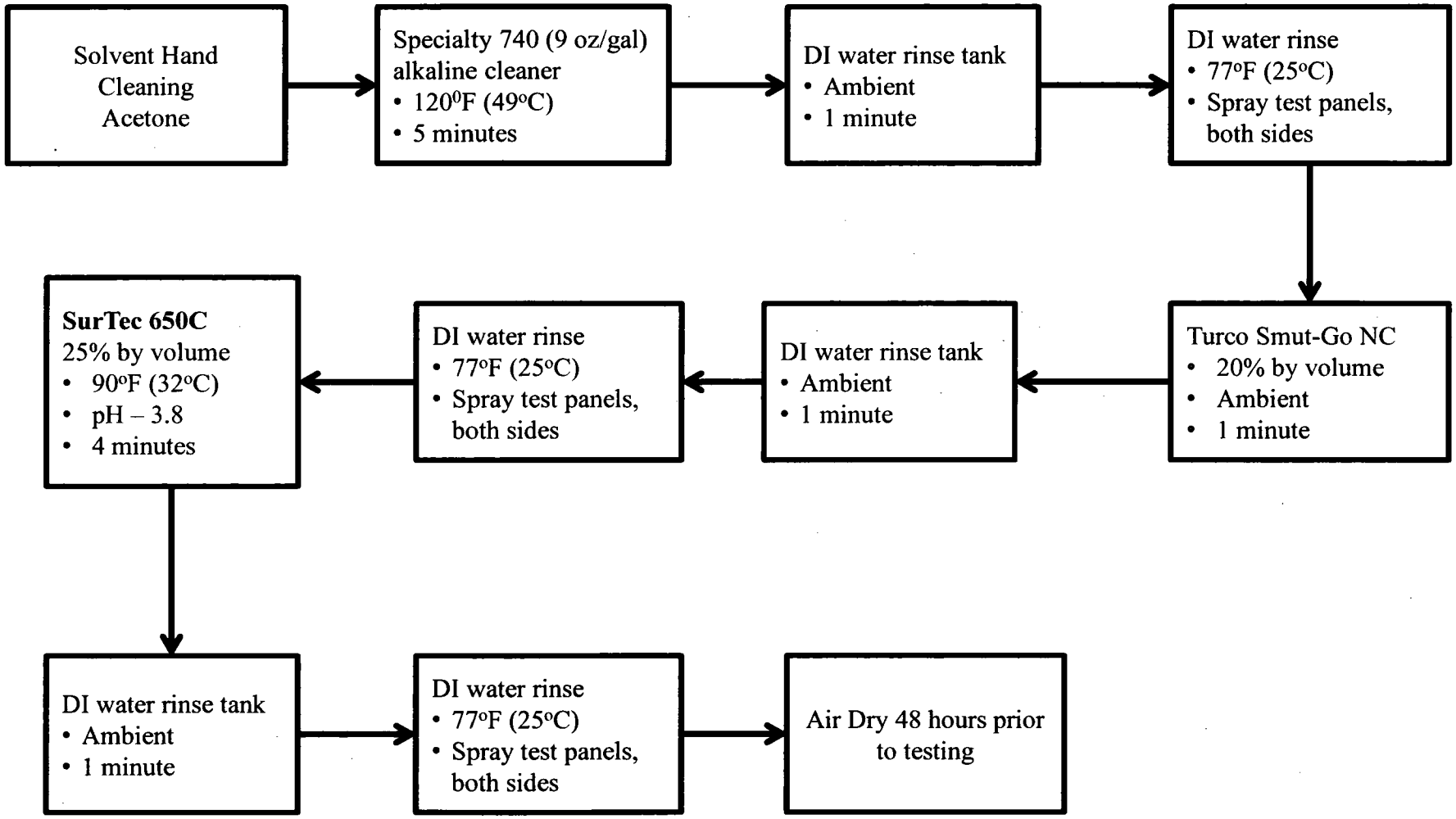
# Metalast TCP HF HPA 100

| **5052-H32** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MT 50 01 | 0 | 0 | | |
| MT 50 02 | 0 | 0 | | |
| MT 50 03 | 0 | 0 | | |

| **6061-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MT 60 01 | 0 | 0 | | |
| MT 60 02 | 0 | 3 | | |
| MT 60 03 | 0 | 0 | | |

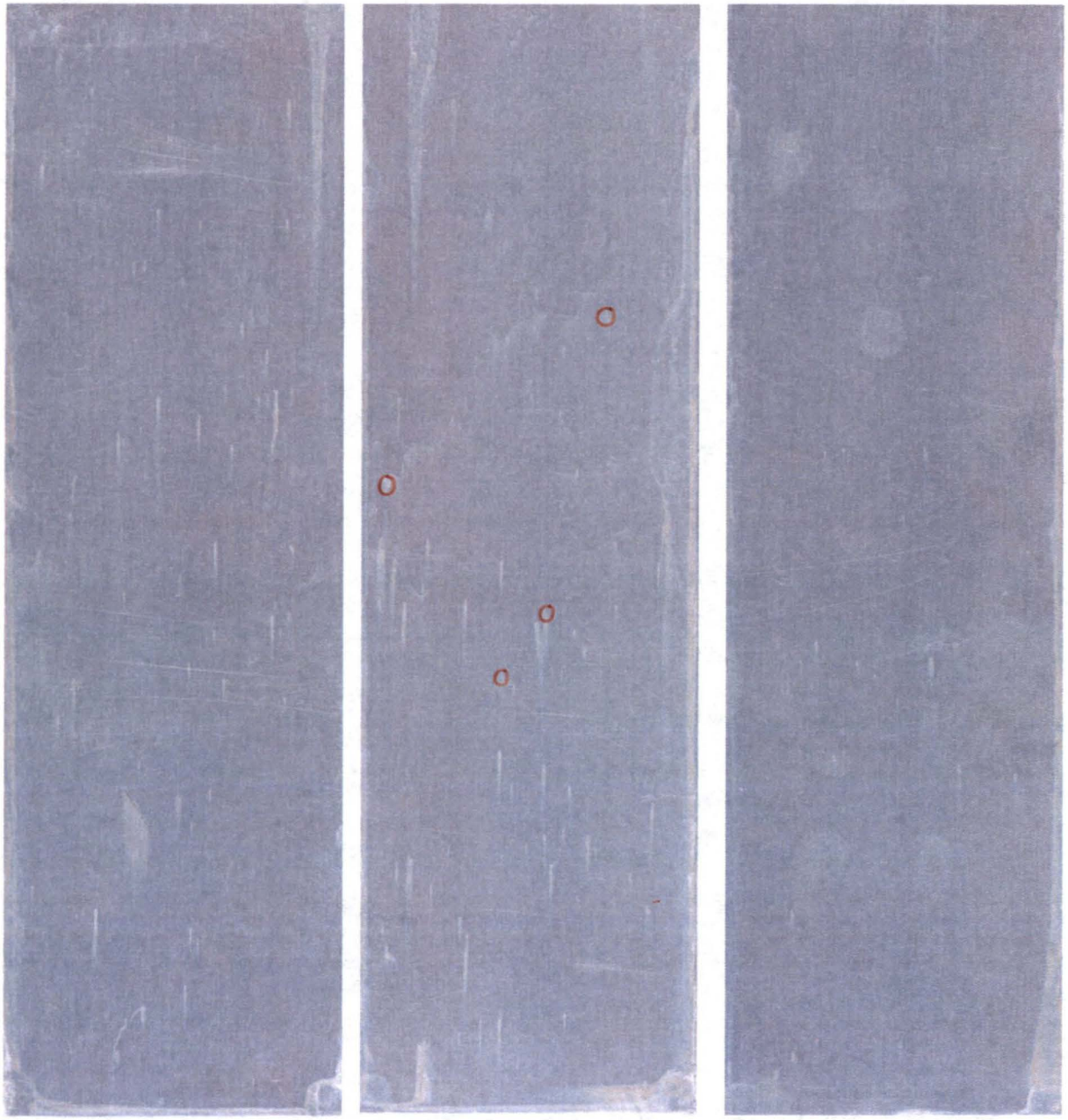
| **7075-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MT 70 01 | 0 | 0 | | |
| MT 70 02 | 0 | 0 | | |
| MT 70 03 | 0 | 0 | | |

# Pretreatment Process: SurTec 650C



# SurTec 650C

| 2024-T3 | @ 168 | @ 336 |
|---|---|---|
| STC 20 01 | 0 | 5+ |
| STC 20 02 | 4 | 5+ |
| STC 20 03 | 5+ | |



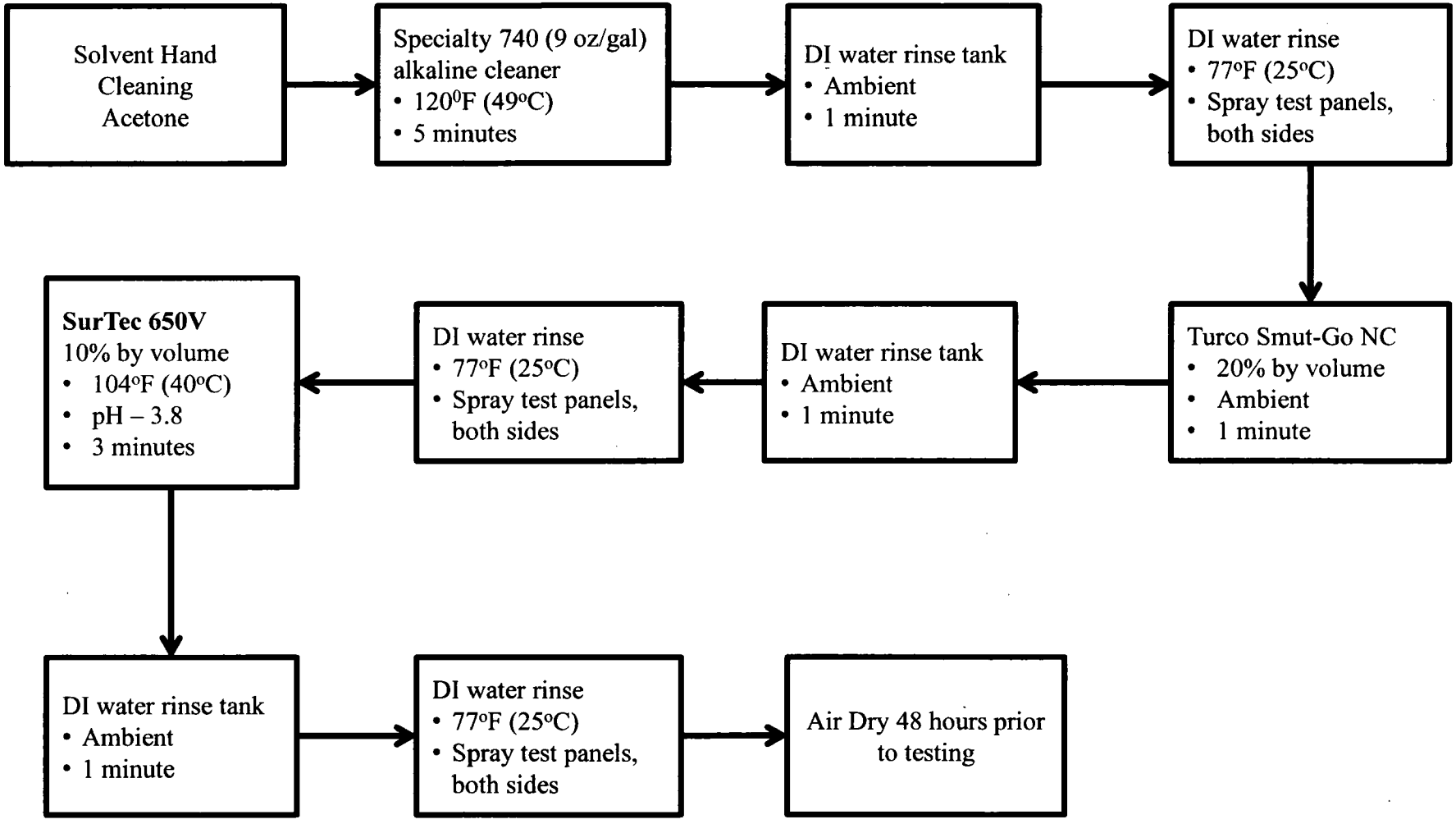
# SurTec 650C

| **5052-H32** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STC 50 01 | 0 | 0 | | |
| STC 50 02 | 0 | 0 | | |
| STC 50 03 | 0 | 0 | | |

| **6061-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STC 60 01 | 0 | 0* | | |
| STC 60 02 | 0 | 0 | | |
| STC 60 03 | 0 | 0 | | |
| 1 pit on edge | | | | |

| **7075-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STC 70 01 | 0 | 0 | | |
| STC 70 02 | 0 | 0 | | |
| STC 70 03 | 0 | 0 | | |

# Pretreatment Process: SurTec 650V



# SurTec 650V

| **2024-T3** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STV 20 01 | 0 | 2 | | |
| STV 20 02 | 0 | 2 | | |
| STV 20 03 | 0 | 3 | | |

| **5052-H32** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STV 50 01 | 0 | 0 | | |
| STV 50 02 | 0 | 0* | | |
| STV 50 03 | 0 | 0 | | |

1 pit on edge

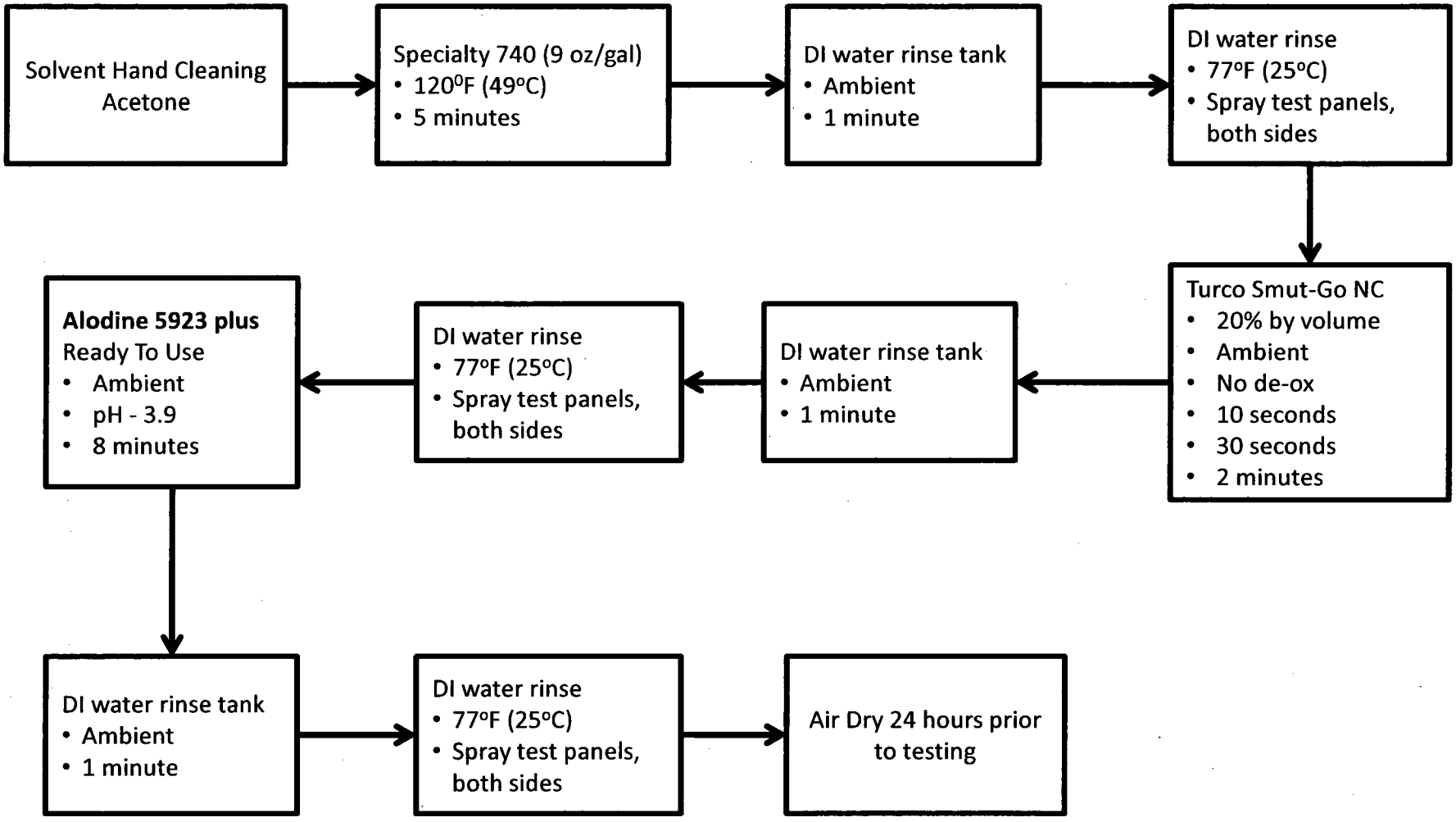
| **6061-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STV 60 01 | 0 | 0 | | |
| STV 60 02 | 0 | 0 | | |
| STV 60 03 | 0 | 0 | | |

| **7075-T6** | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STV 70 01 | 0 | 0 | | |
| STV 70 02 | 0 | 0 | | |
| STV 70 03 | 0 | 0 | | |

# Test Panel Preparation Process Optimization {V}

- Changing times in deoxidizer Turco Smut-Go NC bath
- Only evaluating 2024-T3
- Removed Alodine 1200S

# Pretreatment Process: Alodine 5923 plus



# Alodine 5923 plus

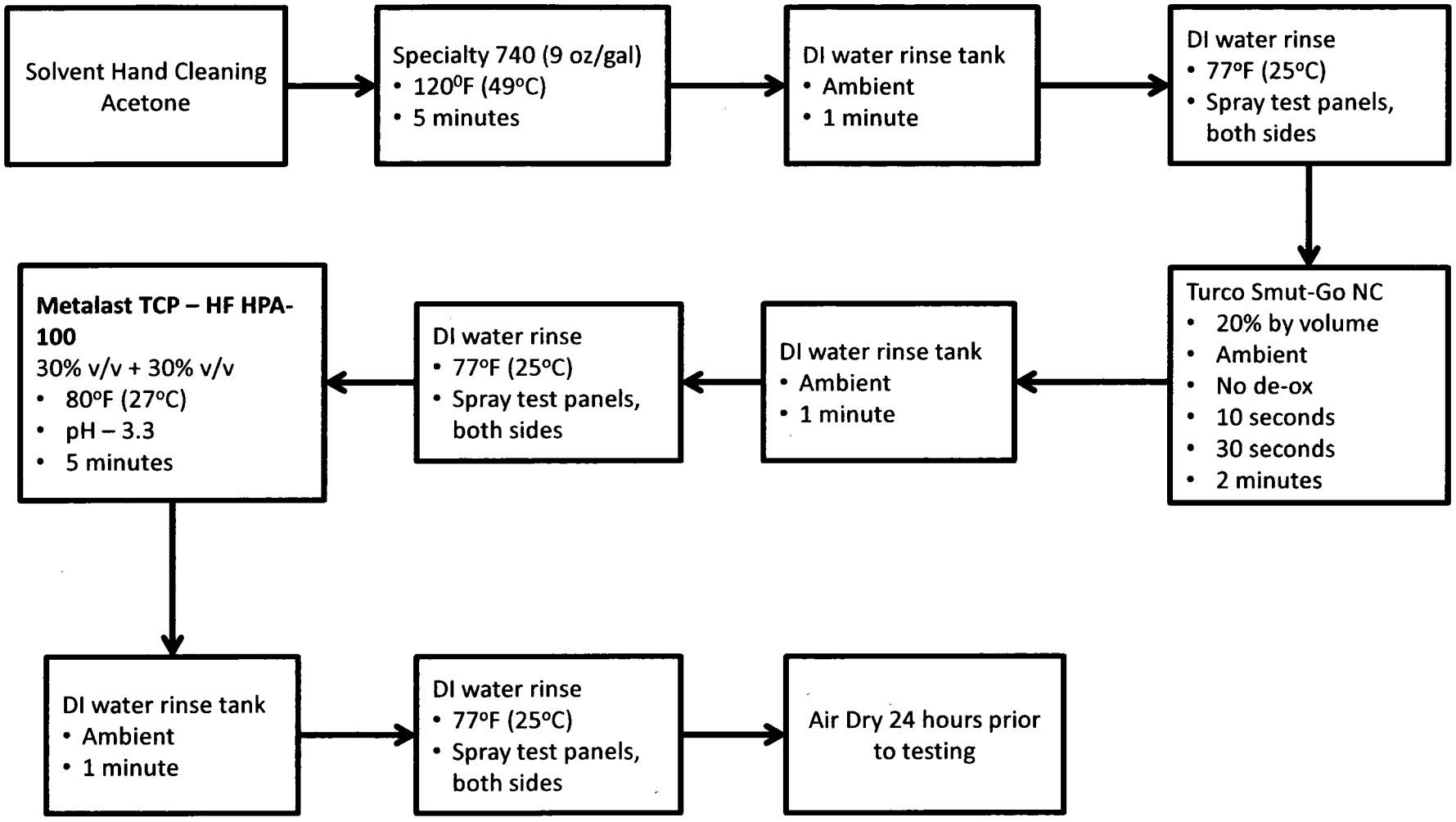
| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL5923 20 0 | | | | |

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL5923 20 10 | | | | |
| AL5923 20 10 | | | | |

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL5923 20 30 | | | | |
| AL5923 20 30 | | | | |
| AL5923 20 30 | | | | |

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| AL5923 20 120 | | | | |
| AL5923 20 120 | | | | |
| AL5923 20 120 | | | | |

# Pretreatment Process: Metalast TCP HF HPA 100



# Metalast TCP HF HPA 100

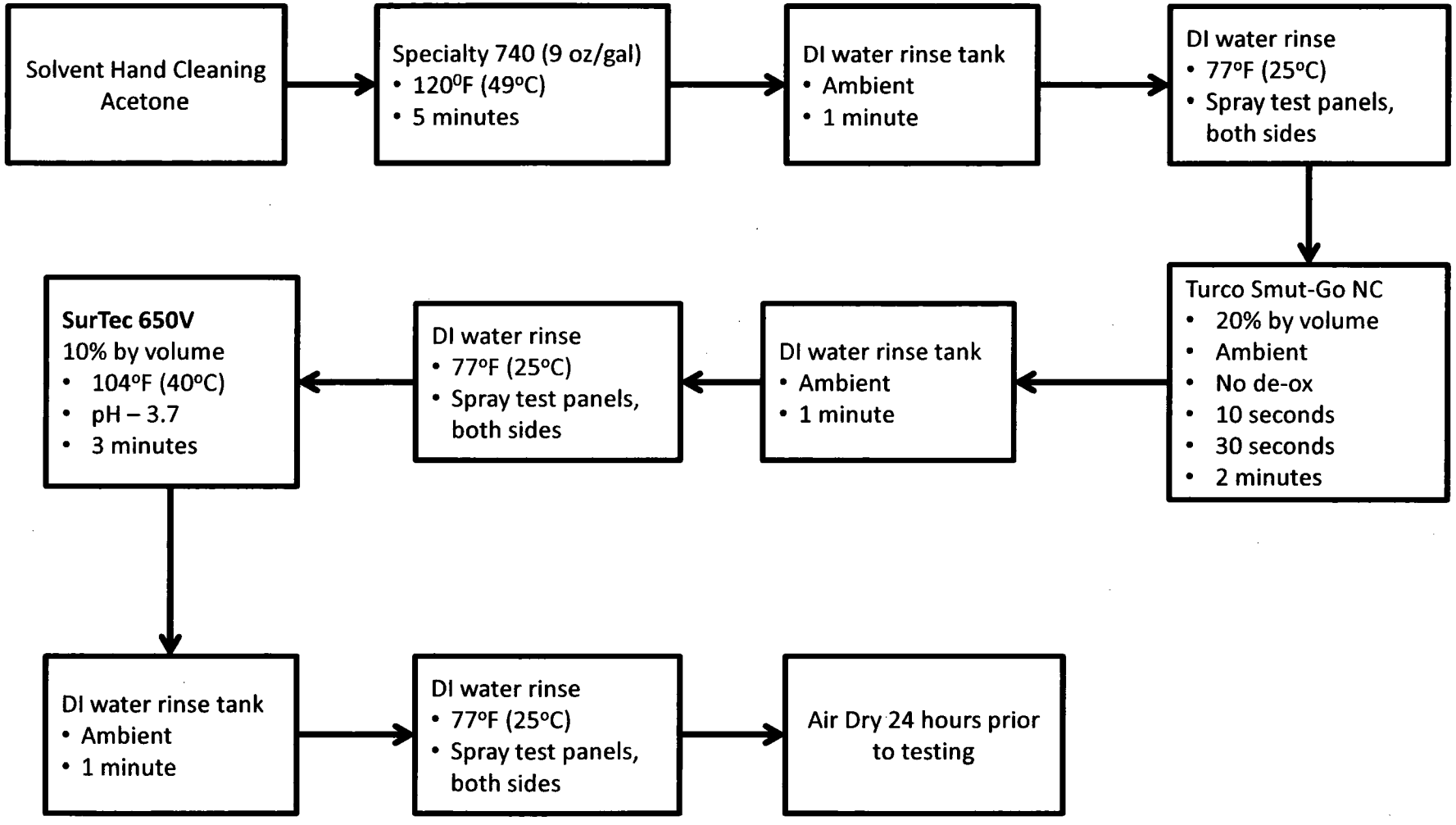
| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MTL 20 0 | | | | |

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MTL 20 10 | | | | |
| MTL 20 10 | | | | |

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MTL 20 30 | | | | |
| MTL 20 30 | | | | |
| MTL 20 30 | | | | |

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| MTL 20 120 | | | | |
| MTL 20 120 | | | | |
| MTL 20 120 | | | | |

# Pretreatment Process: SurTec 650V



## SurTec 650V

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STV 20 0 | | | | |

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STV 20 10 | | | | |
| STV 20 10 | | | | |

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STV 20 30 | | | | |
| STV 20 30 | | | | |
| STV 20 30 | | | | |

| 2024-T3 | @ 168 | @ 336 | @ 504 | @ 672 |
|---|---|---|---|---|
| STV 20 120 | | | | |
| STV 20 120 | | | | |
| STV 20 120 | | | | |

# Hexavalent Chrome Free Coatings – Ground Support Development and Operations Program (GSDOP)

## Electrical Connectors – Electrical Bonding

- Evaluate and test pretreatments not containing hexavalent chrome on electronics housing applications for use on Ground Support Equipment (GSE) and Electrical Ground Support Equipment (EGSE)

# Hexavalent Chrome Free Coatings – Ground Support Development and Operations Program (GSDOP)

## Electrical Connectors – Electrical Bonding

- Evaluate and test pretreatments not containing hexavalent chrome on electronics housing applications for use on Ground Support Equipment (GSE) and Electrical Ground Support Equipment (EGSE)

# Test Articles

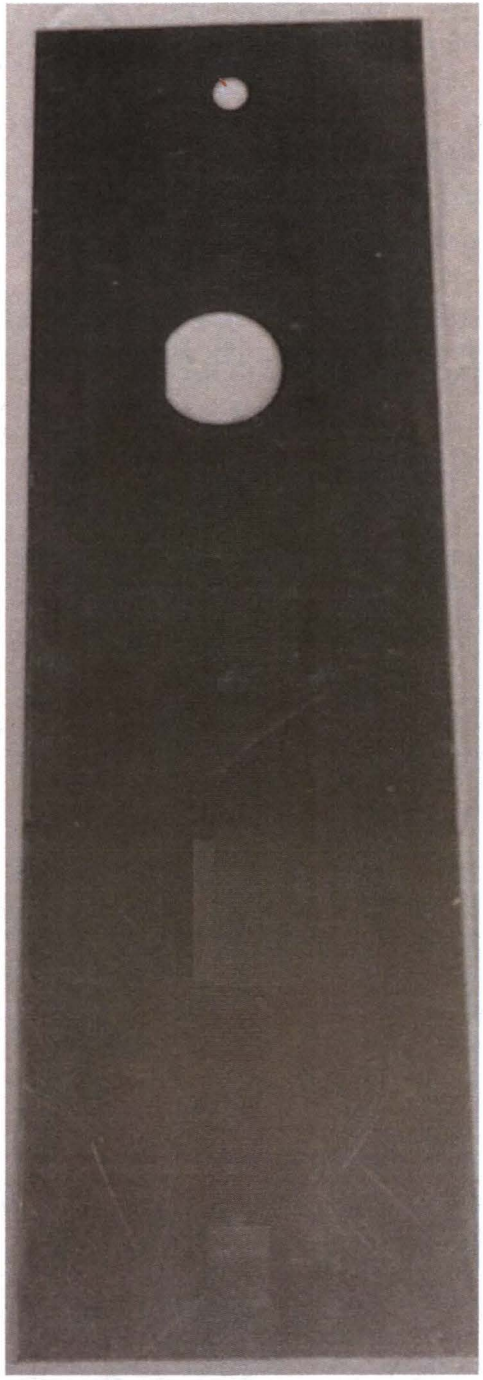
The alloys used in this project have been selected because of their common use in avionics and electronics housing applications. All test panels were procured mill finished without mill markings. Mill finish is as supplied from the mill (raw material manufacturer); is not polished and will most likely have a dull matte appearance. Test panels measured 3"x10"x0.032".

**Alloys used:**

- **5052-H32**
- **6061-T6**

# Test Article Fabrication

## Prior to pretreatment



Drilled 0.25” holes for grounding stud A

Punched D-holes for connector B

# Pretreatment Process

Pretreatment process selected based on previous testing results

## Metalast TCP-HF

| 6061-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| MTL 60 01 | 0 | 0 | 0 | 0 | 0 |
| MTL 60 02 | 0 | 0 | 0 | 0 | 0 |
| MTL 60 03 | 0 | 0 | 0 | 0 | 0 |

| 7075-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| MTL 70 01 | 0 | 0 | 0 | 0 | 0 |
| MTL 70 02 | 0 | 0 | 0 | 0 | 0 |
| MTL 70 03 | 0 | 1 | 1 | 0 | 2 |

## SurTec 650C

| 6061-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| ST 60 01 | 0 | 0 | 0 | 0 | 0 |
| ST 60 02 | 0 | 0 | 0 | 0 | 0 |
| ST 60 03 | 0 | 0 | 0 | 0 | 0 |

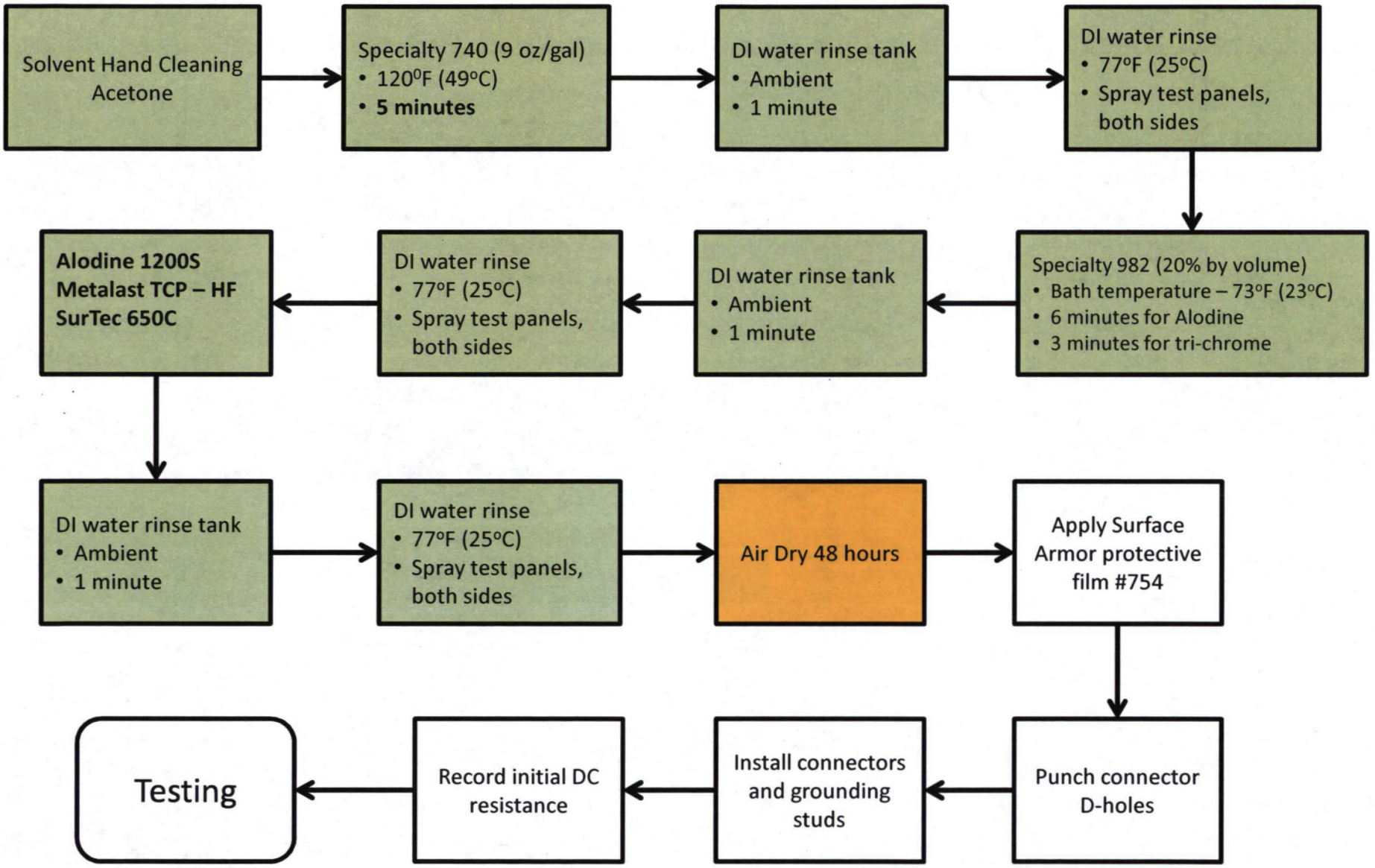
| 7075-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| ST 70 01 | 0 | 1 | 0 | 0 | 1 |
| ST 70 02 | 0 | 0 | 0 | 0 | 0 |
| ST 70 03 | 0 | 1 | 0 | 0 | 1 |

## Alodine 1200S

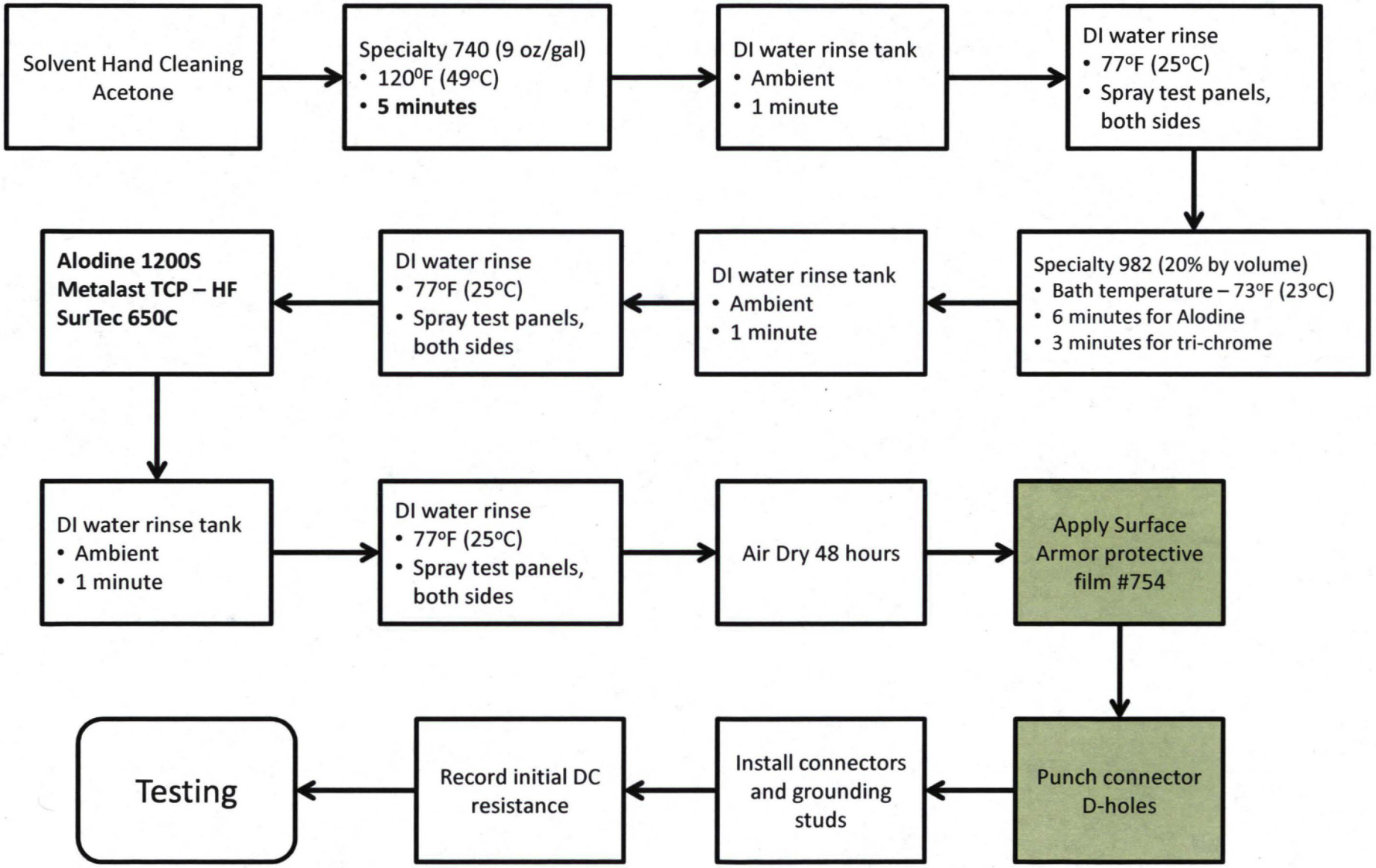
| 6061-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| 1200S 60 01 | 2 | 0 | 0 | 0 | 2 |
| 1200S 60 02 | 5+ | N/A | N/A | N/A | 5+ |
| 1200S 60 03 | 2 | 2 | 2 | 2 | 8 |

| 7075-T6 | @ 168 Hr | @ 336 Hr | @ 504 | @ 672 | Total |
|---|---|---|---|---|---|
| 1200S 70 01 | 0 | 1 | 1 | 2 | 4 |
| 1200S 70 02 | 0 | 0 | 0 | 0 | 0 |
| 1200S 70 03 | 1 | 1 | 2 | 2 | 6 |

# Pretreatment Process

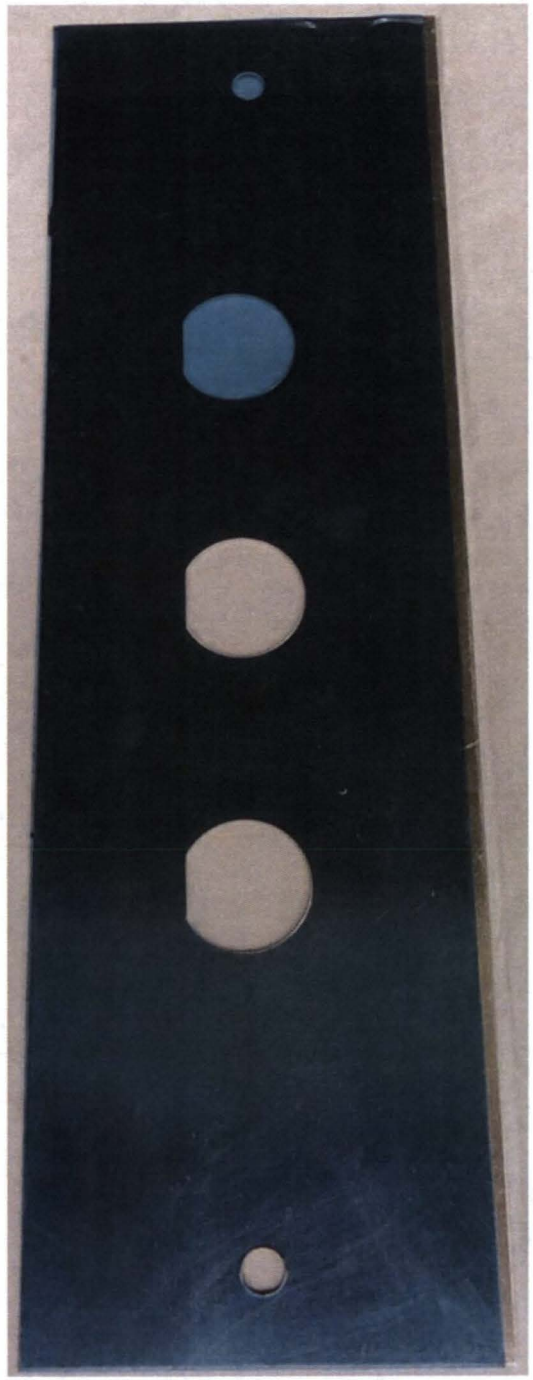


# Test Article Fabrication



# Test Article Fabrication

## After pretreatment

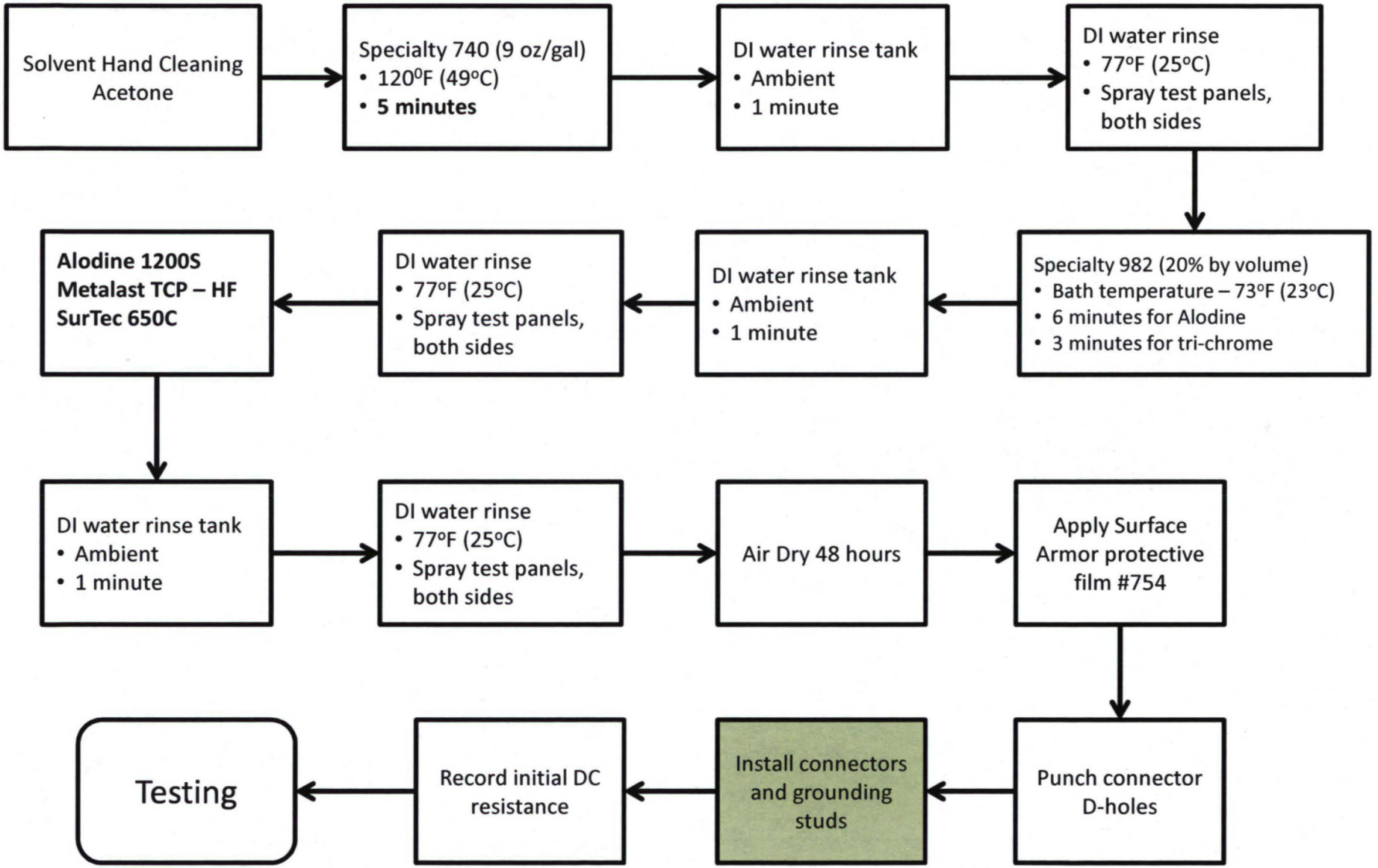


Surface Armor protective film
#754 Applied {Blue PVC Film}
Tack - 5 ounces per lateral inch

Punched D-holes for
connector C-1 and C-2

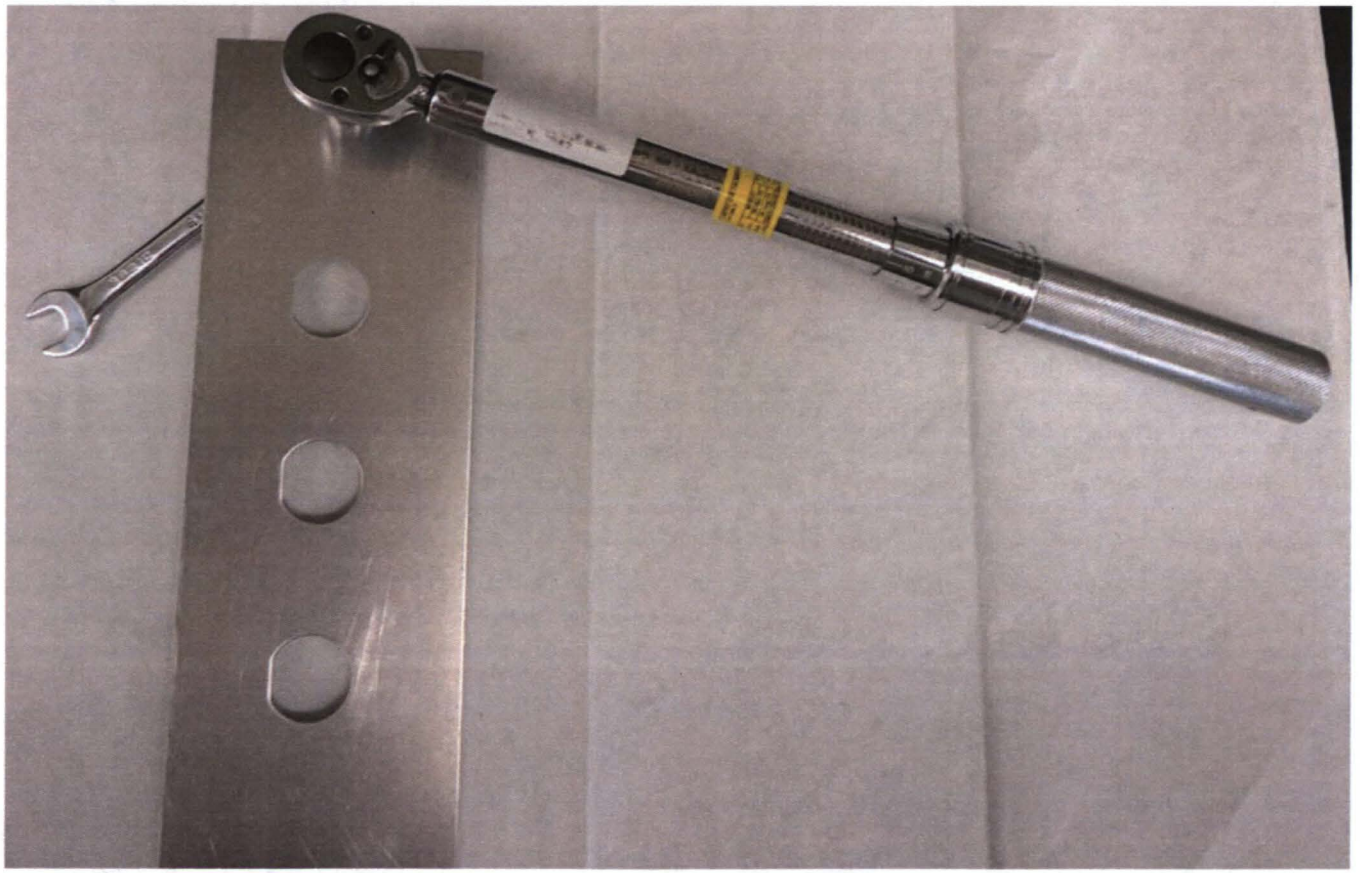
Punched 0.26” holes for
grounding stud D

# Test Article Fabrication



# Test Article Fabrication

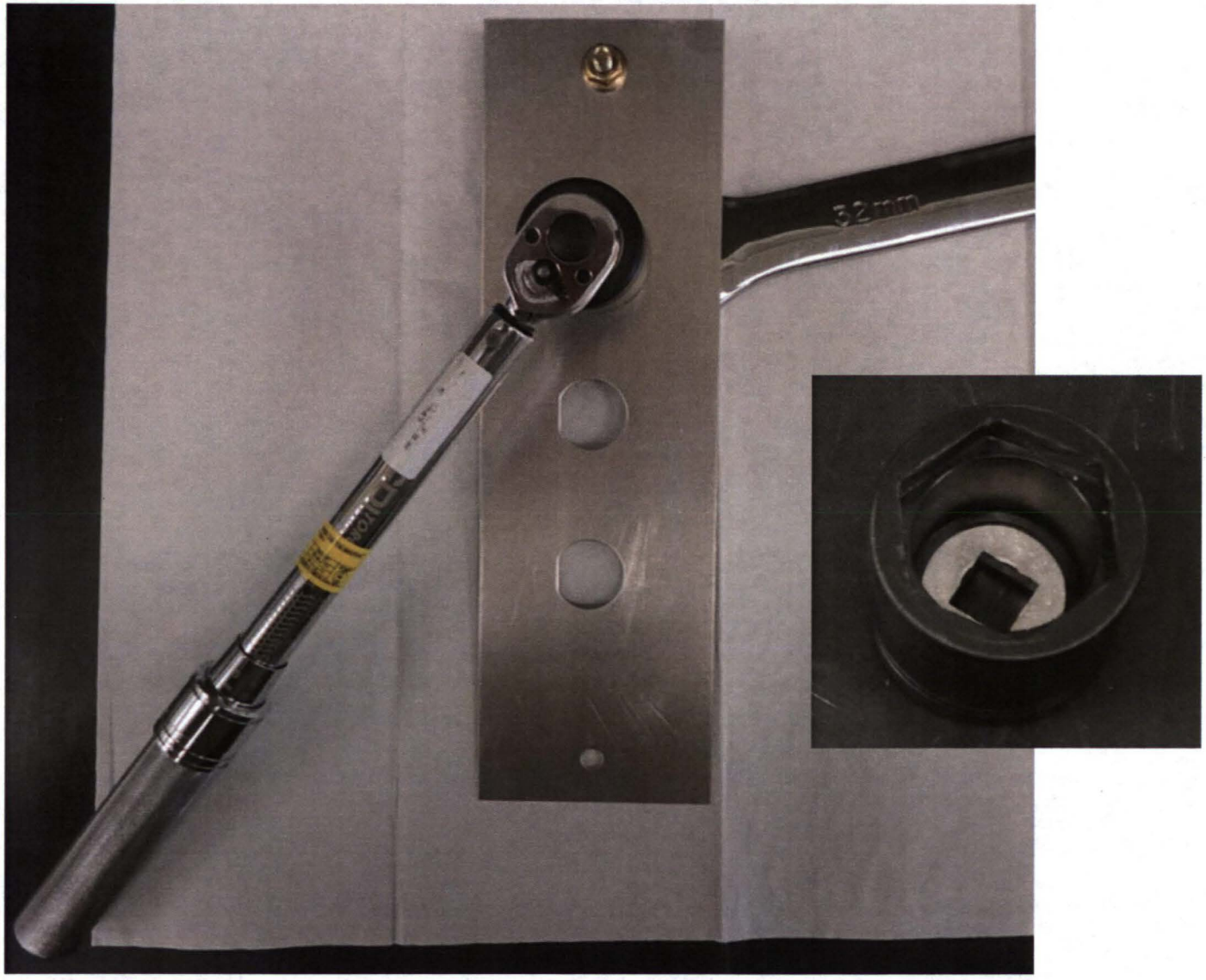
- The grounding studs consist of cadmium plated serrated hex flange bolts (0.5" x .25") with 20 threads per inch. Nuts used to secure the screws to the test articles are cadmium plated serrated hex flange and star tooth locking nuts.
- When installing grounding stud A and connectors B and C-1 non-conductive CERAN HVA grease was used per KSC Standard Drawing Notes; "Apply a thin, continuous coating of grease (CERAN HVA) to faying surfaces. After installing connectors, remove excess grease with a clean, dry, lint-free rag".
- The grounding stud serrated hex flange locking and star tooth nuts were torqued to **35 inch pounds**.



# Test Article Fabrication

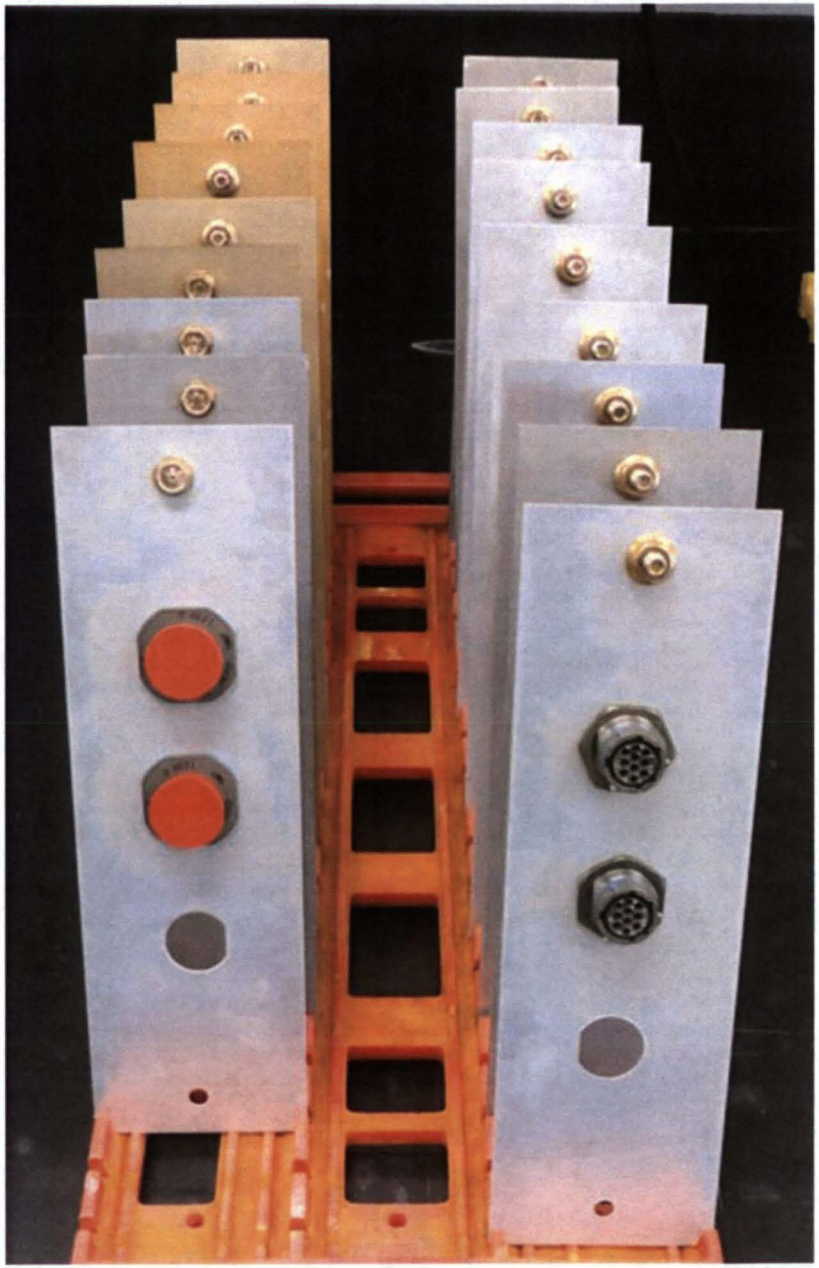
# Test Article Fabrication

- The connector receptacles consist of part number: MS3474W12 – 10S
- The connector jam nuts were torqued to **35 inch pounds**



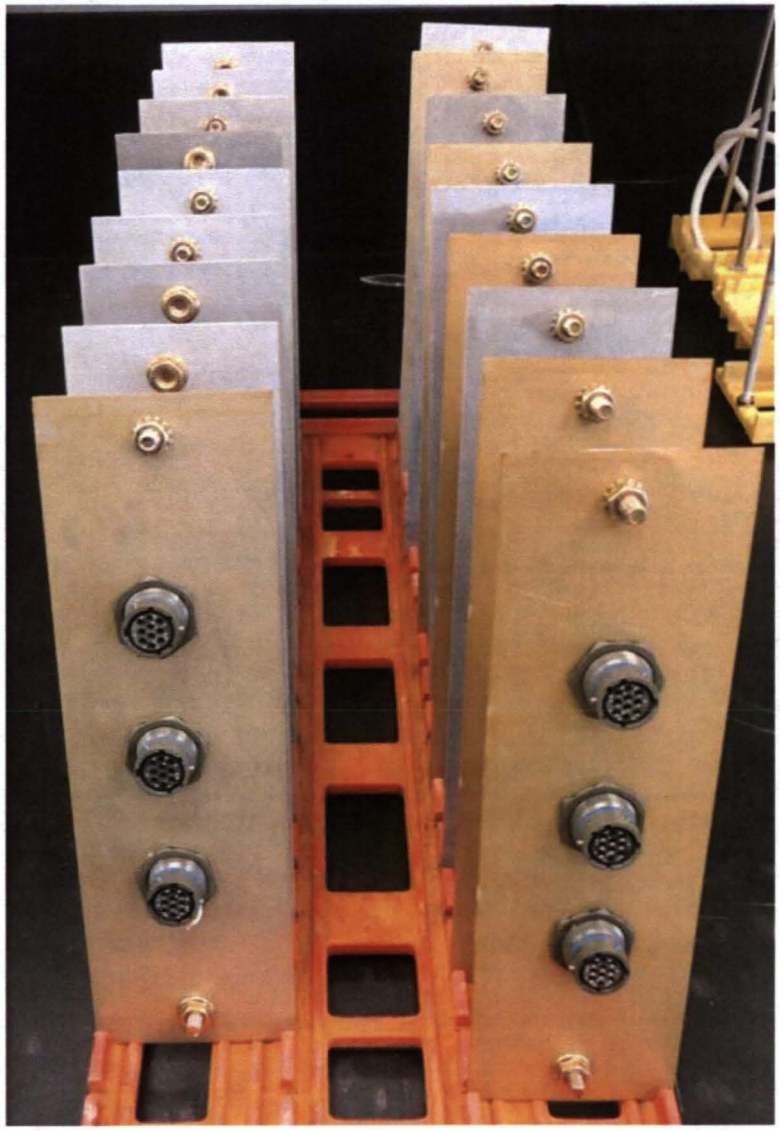
# Test Article Fabrication

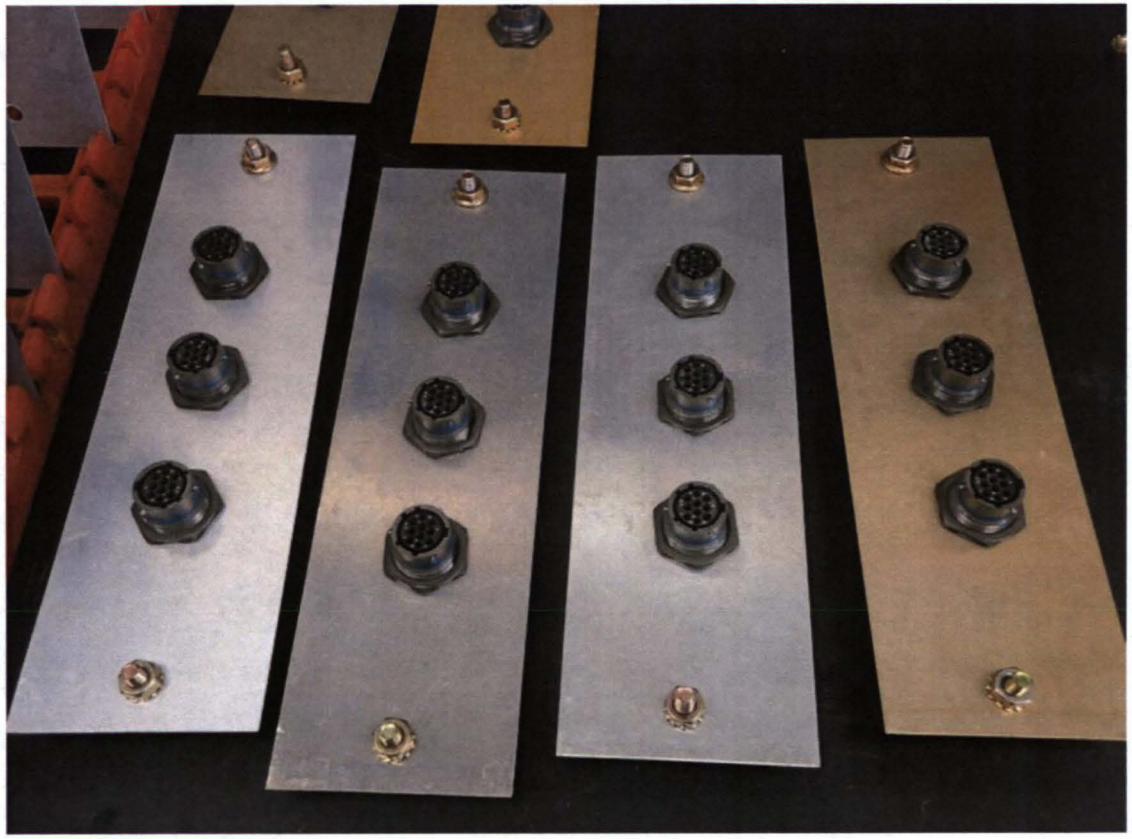
# Test Article Fabrication



CERAN HVA grease was <u>not</u> used when installing connector C-2 and grounding stud D

# Test Article Fabrication

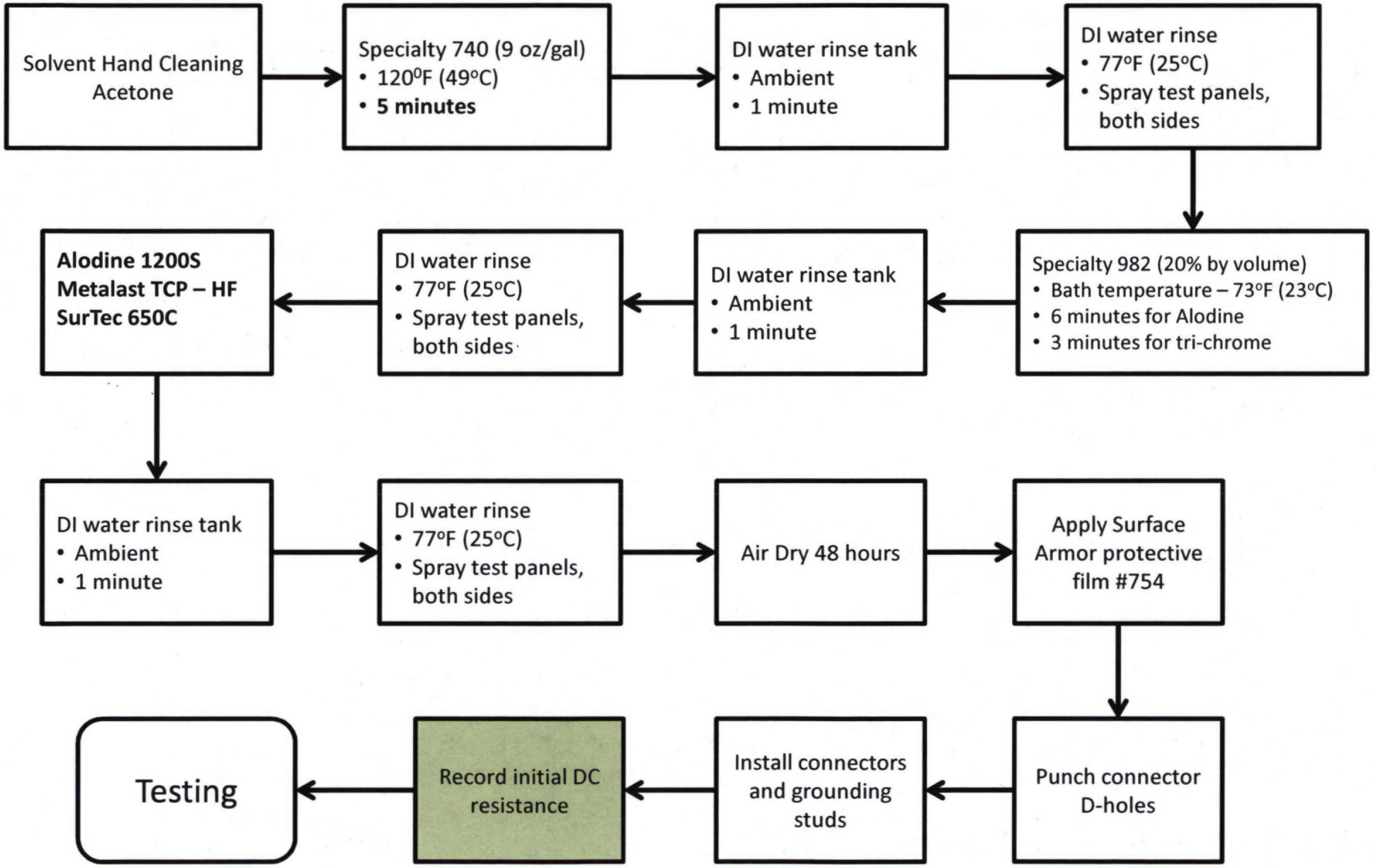




# Test Article Fabrication

Connector caps added to prevent moisture and salt spray from accumulating inside the connector during beach front testing

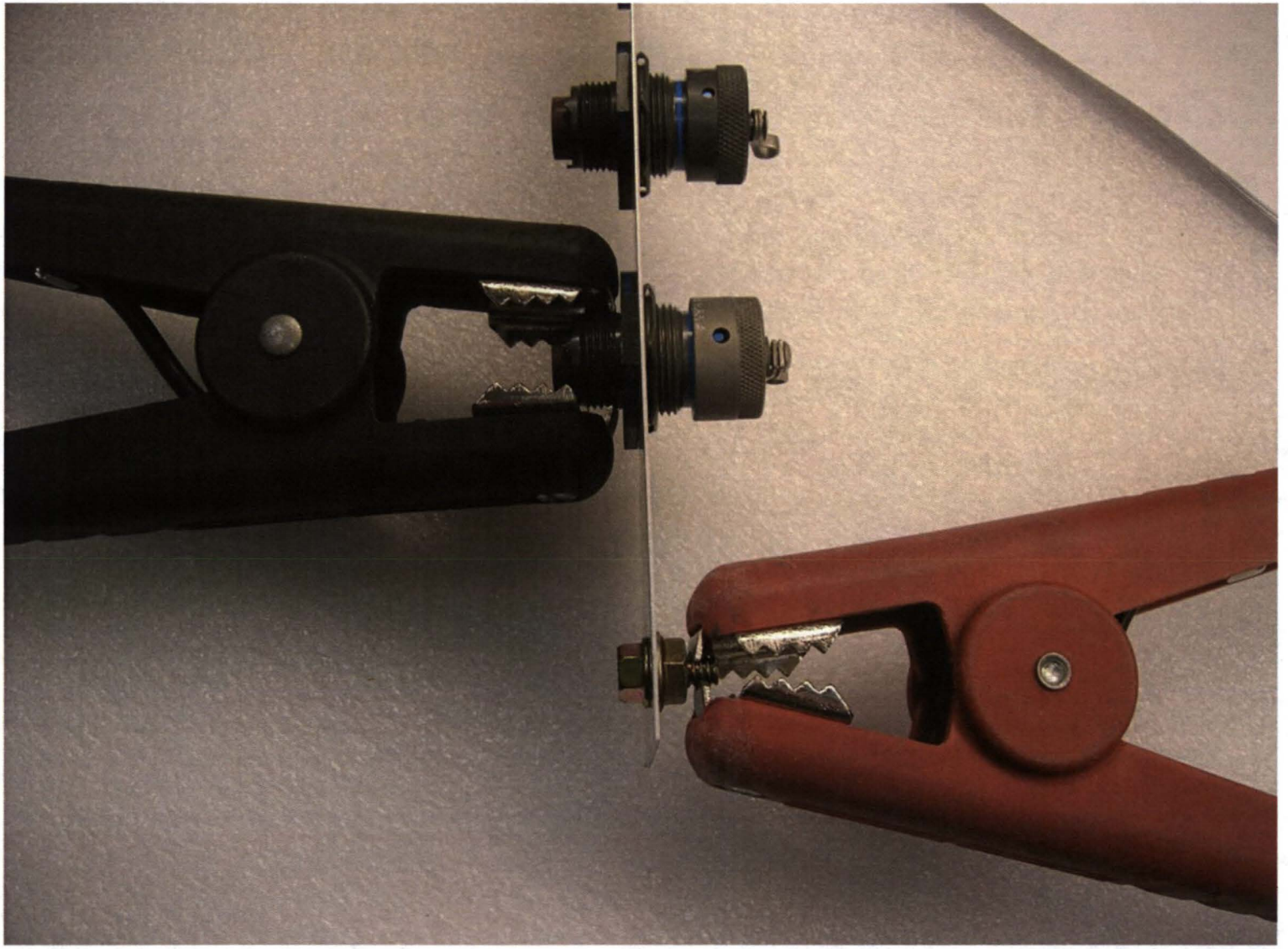
# DC Resistance Measurements



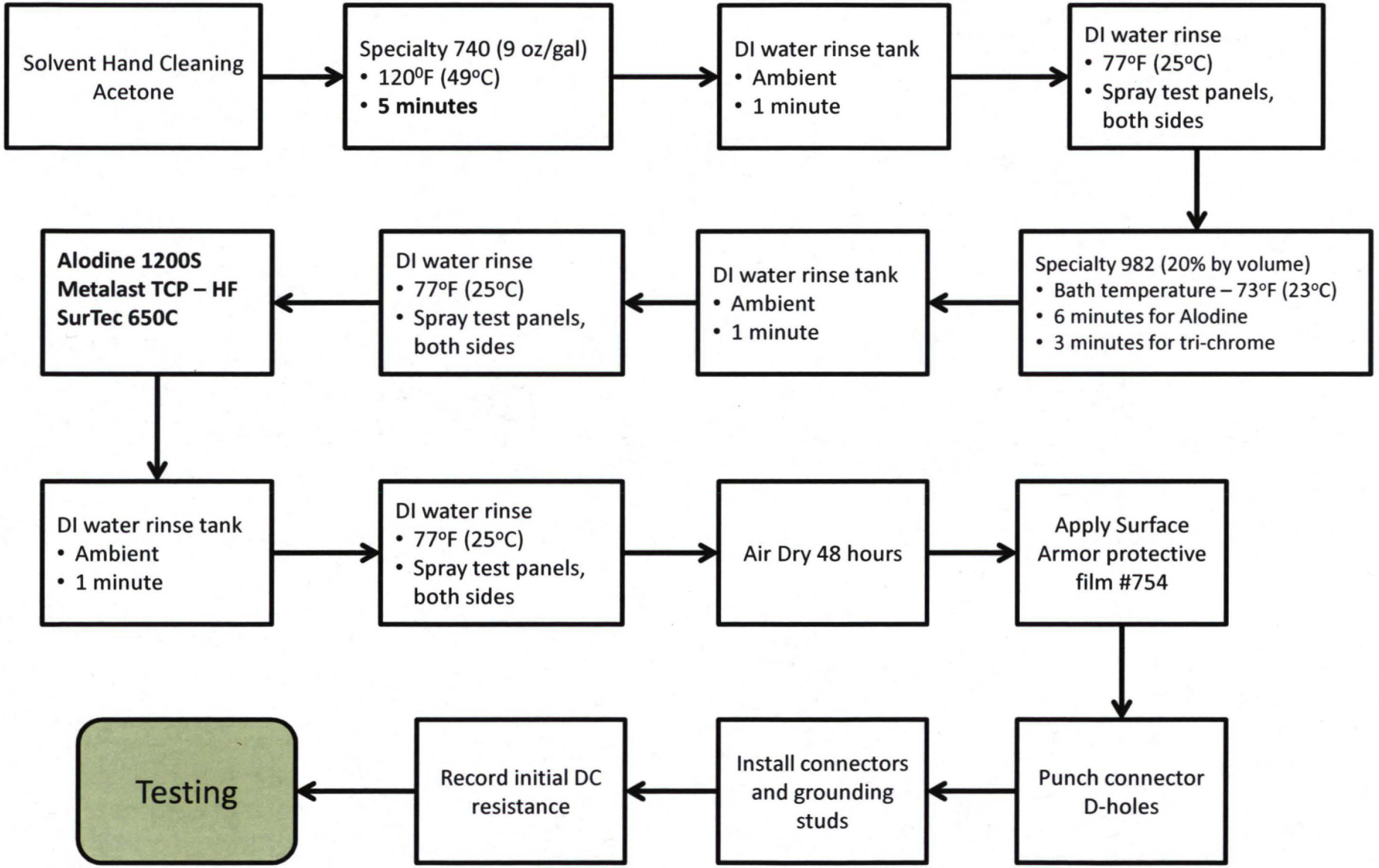
# DC Resistance Measurements

- Measure the DC resistance between connector shells to grounding studs per NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment, section 4.3.1. The DC resistance from backshell to case (grounding stud) shall not exceed 2.5 milliohms
- During initial measurements, is was determined that some of the connectors had initial DC measurements grater than the 2.5 milliohms limit.
- The connectors were loosened and then torqued back to **35 inch pounds**

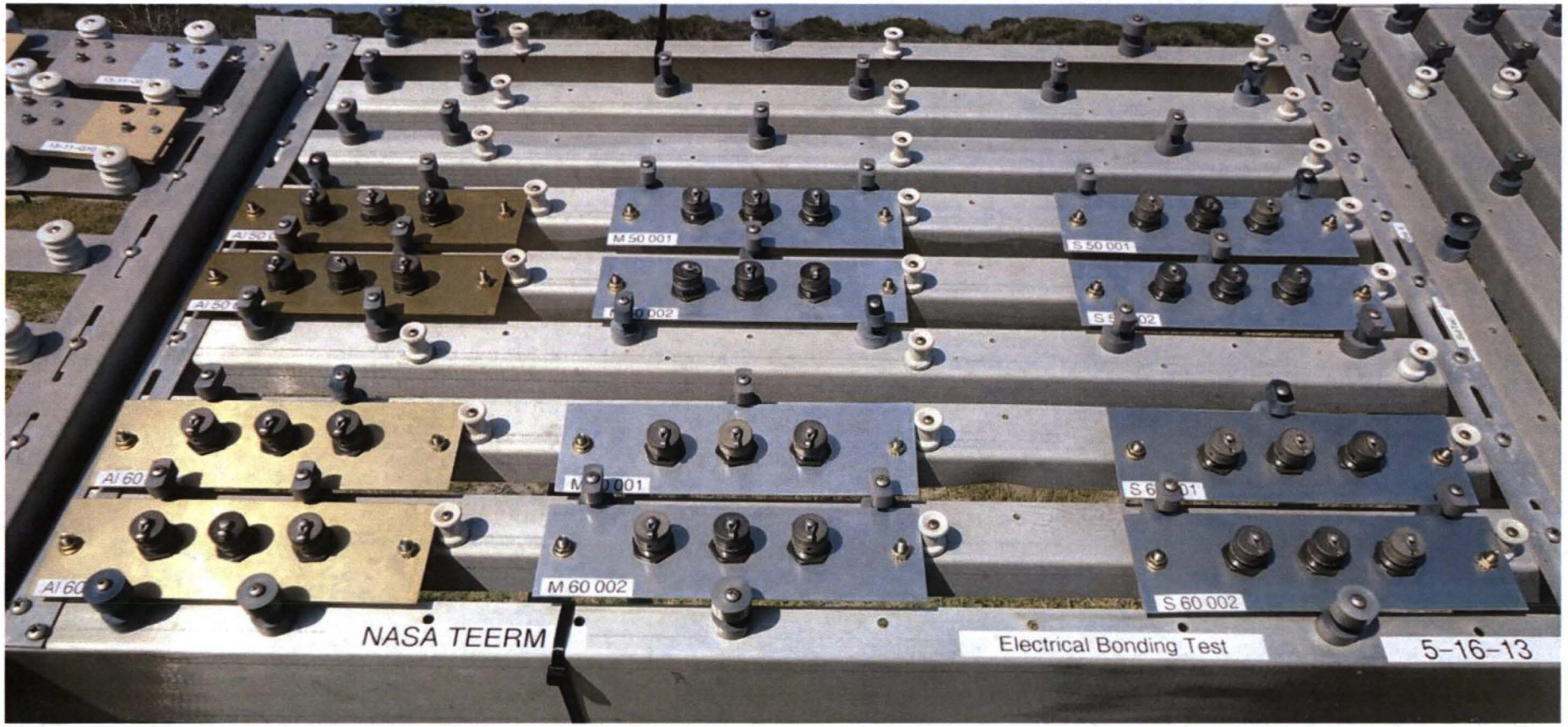
# Initial DC Resistance Measurements



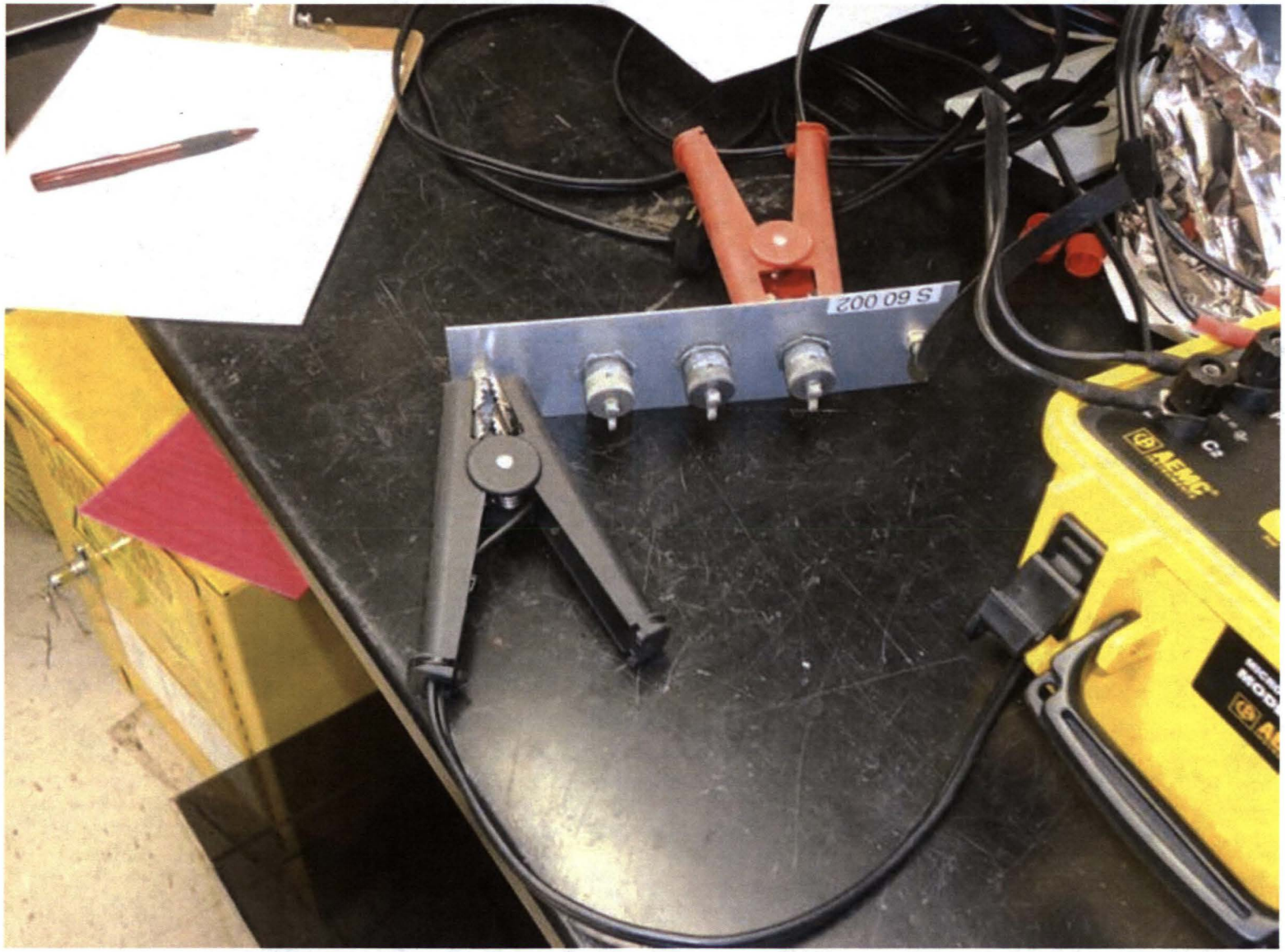
# ASTM B 117 Testing



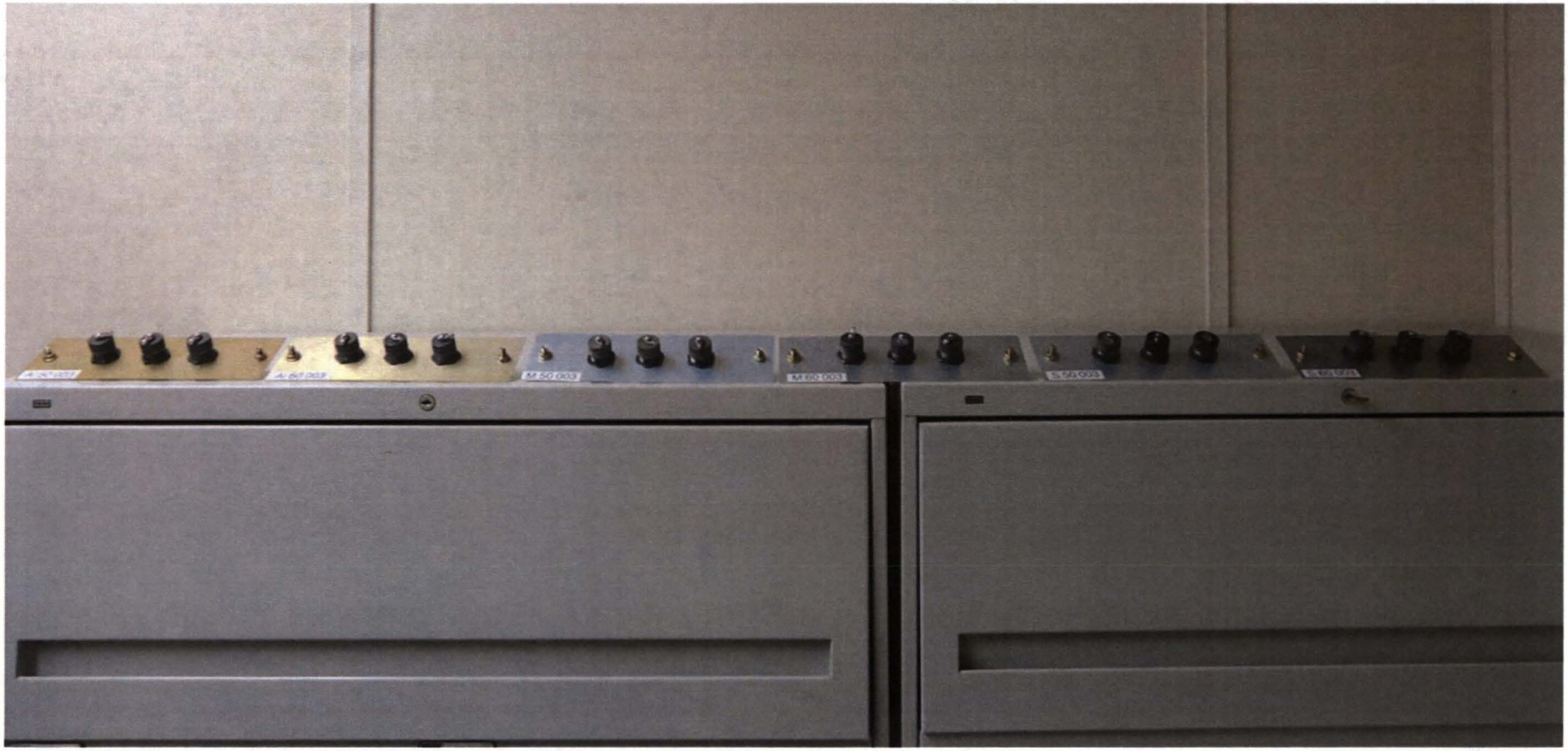
# KSC Beach Front Testing



# DC Resistance Measurements at the KSC Beachfront Lab



# Ambient Office Storage



## DC Resistance Measurements Alodine 1200S

- Connectors with initial DC resistance readings greater than 2.5 milliohms were loosened and again torqued to 35 inch pounds
- If the resistance readings continued to be above 2.5 milliohms, the connectors were deemed failed

| | | | | | Initial | 35 days | | |
|---|---|---|---|---|---|---|---|---|
| Pretreatment | Panel # | Substrate | Test | Grounding stud A | Average | Average | % Change | Stud to stud* |
| Alodine 1200S | Al 50 - 001 | 5052-H32 | Beach | Connector B | 1.3850 | 9.1707 | 562.16% | |
| | | | | Connector C-1 | 0.7646 | 2.7057 | 253.87% | |
| | | | | Connector C-2 | 0.8047 | 1.8770 | 133.24% | |
| | | | | Grounding stud D | | | | 0.9985 |
| | | | | Connector B | 1.0162 | 7.8450 | 671.99% | |
| | | | | Connector C-1 | 0.3181 | 2.1733 | 583.22% | |
| | | | | Connector C-2 | 0.2267 | 1.6373 | 622.35% | |
| Alodine 1200S | Al 50 - 002 | 5052-H32 | Beach | Grounding stud A | | | | |
| | | | | Connector B | 1.5985 | 25.5797 | 1500.26% | |
| | | | | Connector C-1 | 0.3813 | 1.0292 | 169.91% | |
| | | | | Connector C-2 | 3.3059 | 9.2367 | 179.40% | |
| | | | | Grounding stud D | | | | 0.6016 |
| | | | | Connector B | 1.6092 | 30.7220 | 1809.11% | |
| | | | | Connector C-1 | 0.2960 | 0.9343 | 215.65% | |
| | | | | Connector C-2 | 4.2364 | 8.0200 | 89.31% | |
| Alodine 1200S | Al 50 - 003 | 5052-H32 | Stored | Grounding stud A | | | | |
| | | | | Connector B | 0.3341 | 13.6783 | 3994.08% | |
| | | | | Connector C-1 | 0.6059 | 4.3146 | 612.06% | |
| | | | | Connector C-2 | 0.6814 | 1.7453 | 156.13% | |
| | | | | Grounding stud D | | | | 0.5544 |
| | | | | Connector B | 2.9204 | 8.2047 | 180.94% | |
| | | | | Connector C-1 | 0.4795 | 4.1967 | 775.22% | |
| | | | | Connector C-2 | 0.4906 | 1.5465 | 215.20% | |
| Alodine 1200S | Al 60 - 001 | 6061-T6 | Beach | Grounding stud A | | | | |
| | | | | Connector B | 1.3479 | 2.5959 | 92.59% | |
| | | | | Connector C-1 | 1.5331 | 12.1003 | 689.26% | |
| | | | | Connector C-2 | 1.6506 | 5.0783 | 207.67% | |
| | | | | Grounding stud D | | | | 2.3748 |
| | | | | Connector B | 0.2957 | 0.7789 | 163.41% | |
| | | | | Connector C-1 | 0.3907 | 10.5247 | 2593.80% | |
| | | | | Connector C-2 | 1.8686 | 3.1082 | 66.34% | |
| Alodine 1200S | Al 60 - 002 | 6061-T6 | Beach | Grounding stud A | | | | |
| | | | | Connector B | 0.5995 | 2.2975 | 283.26% | |
| | | | | Connector C-1 | 0.6637 | 6.4550 | 872.58% | |
| | | | | Connector C-2 | 0.7269 | 1.5479 | 112.96% | |
| | | | | Grounding stud D | | | | 0.6631 |
| | | | | Connector B | 0.5186 | 2.1763 | 319.67% | |
| | | | | Connector C-1 | 0.5291 | 6.2967 | 1090.00% | |
| | | | | Connector C-2 | 0.4822 | 1.4030 | 190.95% | |
| Alodine 1200S | Al 60 - 003 | 6061-T6 | Stored | Grounding stud A | | | | |
| | | | | Connector B | 1.6031 | 5.0313 | 213.85% | |
| | | | | Connector C-1 | 1.6318 | 2.5952 | 59.04% | |
| | | | | Connector C-2 | 1.6647 | 2.4727 | 48.54% | |
| | | | | Grounding stud D | | | | 2.5019 |
| | | | | Connector B | 1.0729 | 3.1671 | 195.20% | |
| | | | | Connector C-1 | 0.2995 | 0.5970 | 99.34% | |
| | | | | Connector C-2 | 0.2536 | 0.3840 | 51.42% | |

* Stud to stud following 35 days of exposure

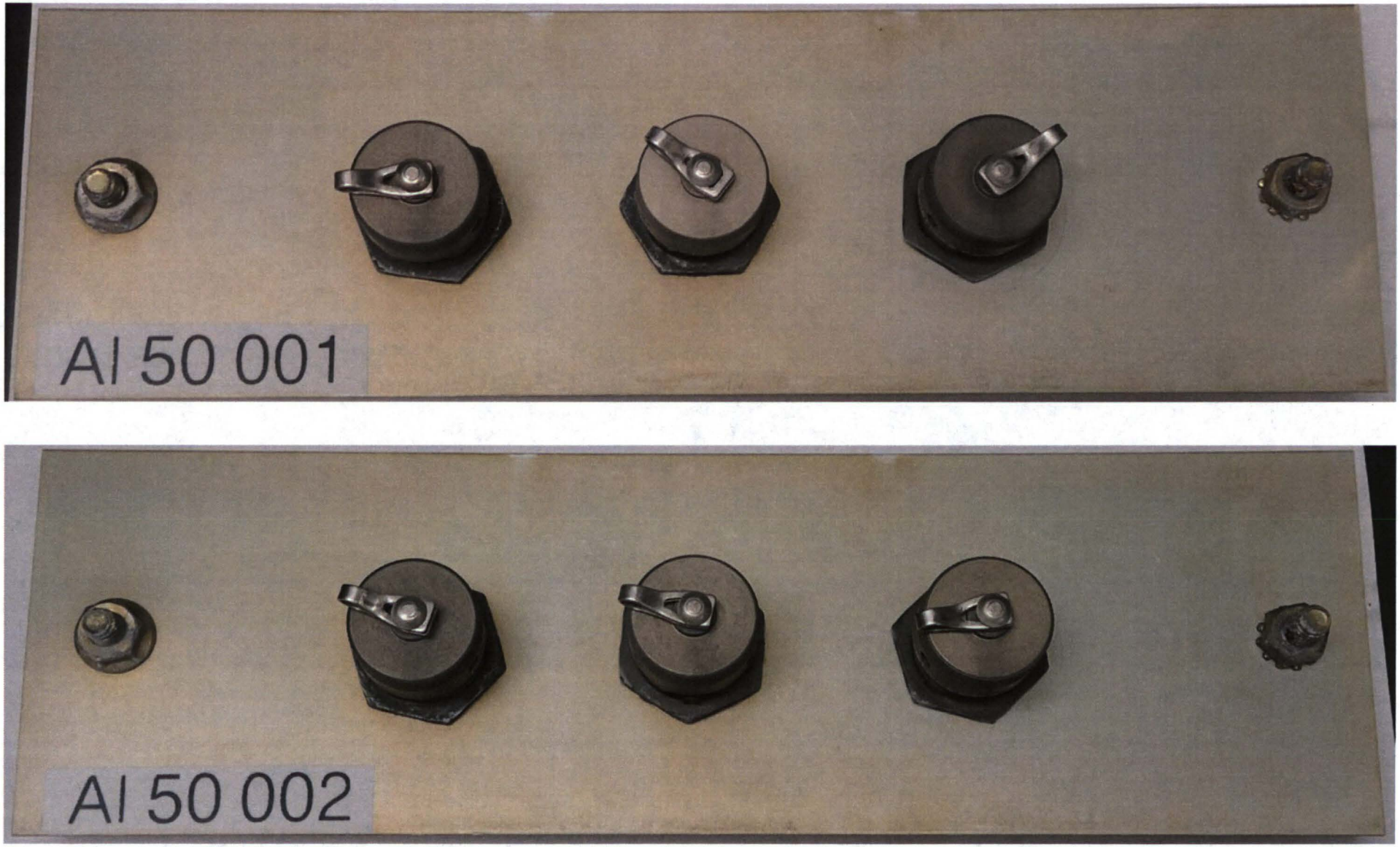
**DC resistance readings from 5052-H32 test panels following 35 days of exposure at the KSC Beachfront**

**Alodine 1200S**

| Ground | Connector | Pass | Fail |
|---|---|---|---|
| Stud A | B | 0 | 2 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 1 | 1 |
| | Hole punched after pretreatment | | |
| Hole drilled prior to pretreatment | CERAN HVA grease used during install | | |
| | C-2* | 1 | 1 |
| CERAN HVA grease used during install | Hole punched after pretreatment | | |
| | No CERAN HVA grease used during install | | |
| Stud D | B | 0 | 2 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 2 | 0 |
| | Hole punched after pretreatment | | |
| Hole punched after pretreatment | CERAN HVA grease used during install | | |
| | C-2* | 1 | 1 |
| No CERAN HVA grease used during install | Hole punched after pretreatment | | |
| | No CERAN HVA grease used during install | | |

* Failed initial reading on test panel Al 50 - 002

5052-H32 test panels following 35 days of exposure at the KSC Beachfront

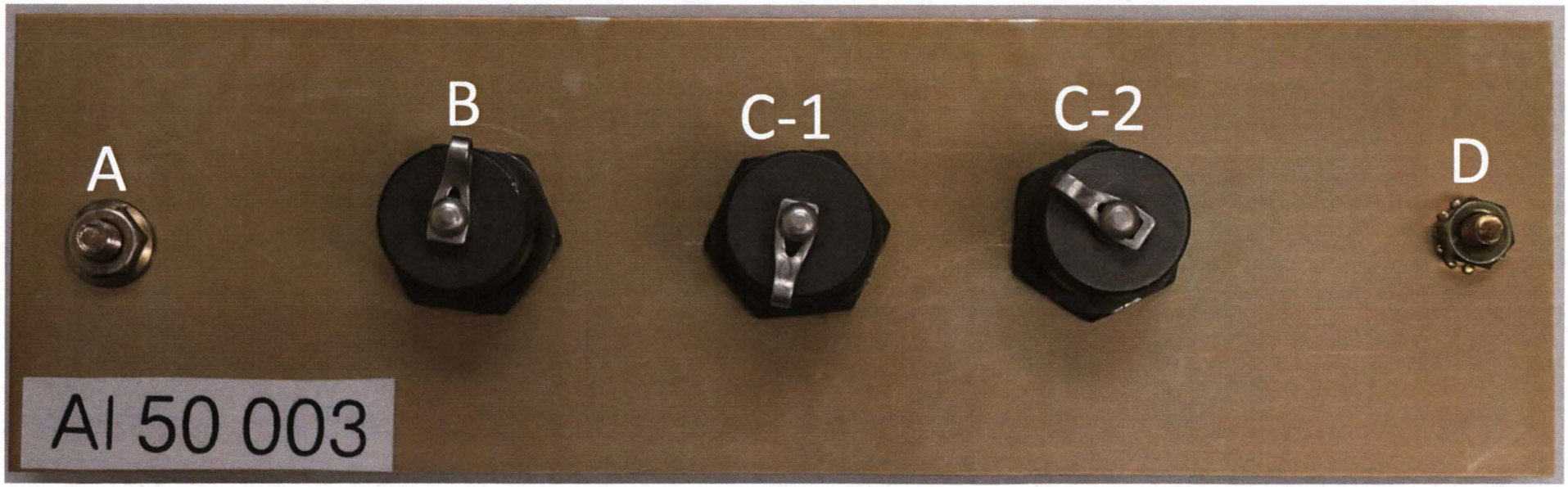


**DC resistance readings from 5052-H32 test panels following 35 days of ambient office storage**

**Alodine 1200S**

| Ground | Connector | Pass | Fail |
|---|---|---|---|
| Stud A | B | 0 | 1 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 0 | 1 |
| | Hole punched after pretreatment | | |
| Hole drilled prior to pretreatment | CERAN HVA grease used during install | | |
| | C-2 | 1 | 0 |
| | Hole punched after pretreatment | | |
| CERAN HVA grease used during install | No CERAN HVA grease used during install | | |
| Stud D | B* | 0 | 1 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 0 | 1 |
| | Hole punched after pretreatment | | |
| Hole punched after pretreatment | CERAN HVA grease used during install | | |
| | C-2 | 1 | 0 |
| | Hole punched after pretreatment | | |
| No CERAN HVA grease used during install | No CERAN HVA grease used during install | | |

* Failed initial reading on test panel Al 50 - 003

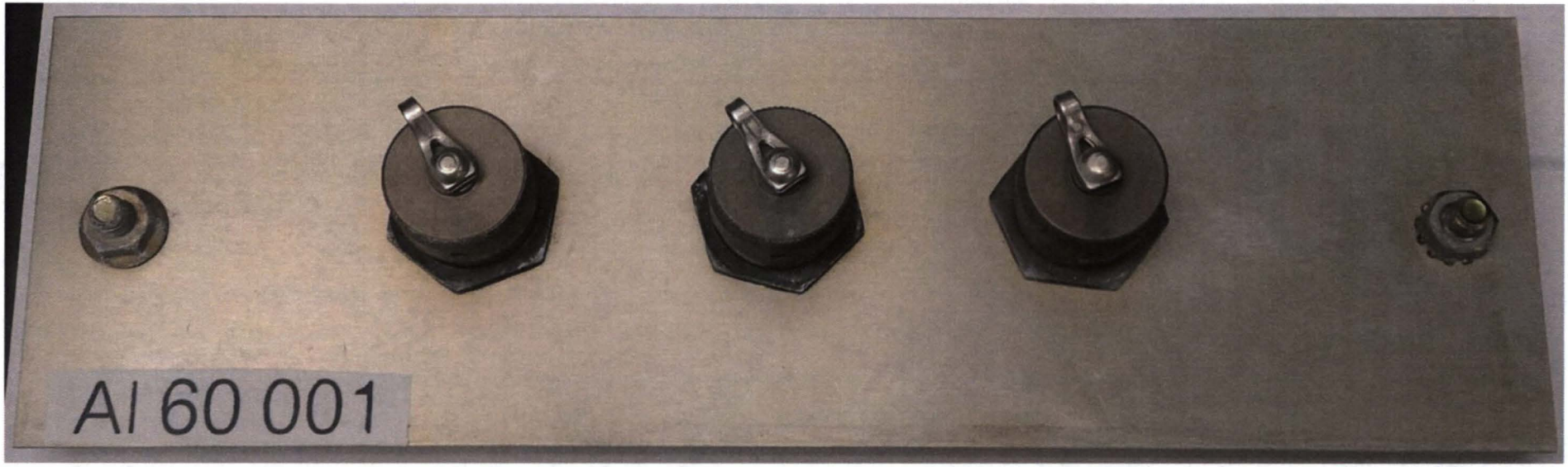


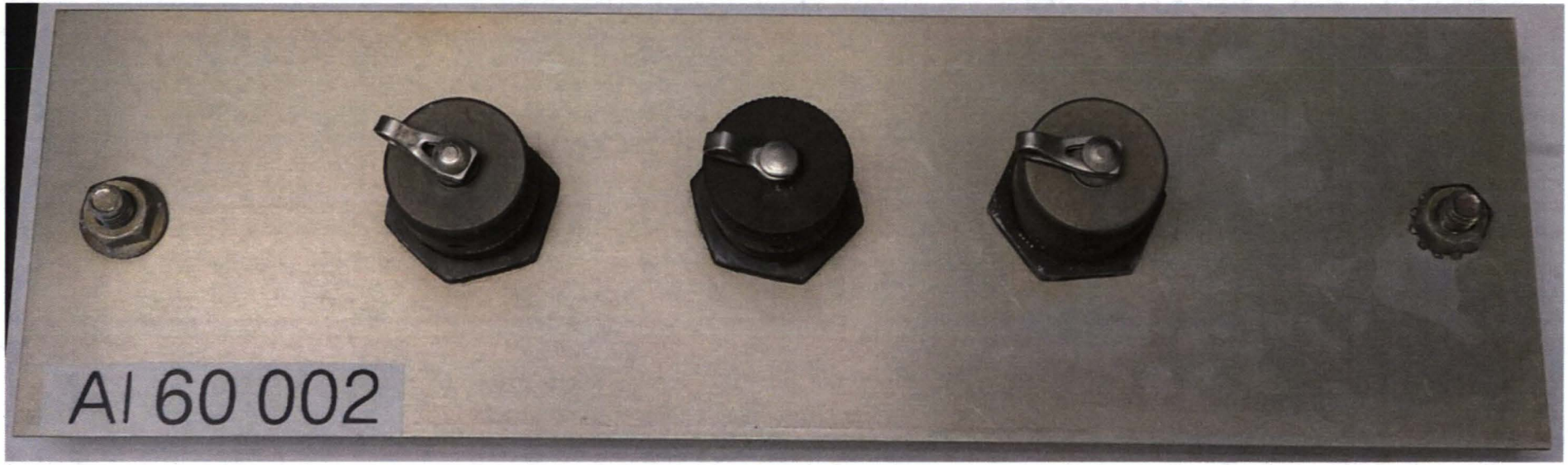
**DC resistance readings from 6061-T6 test panels following 35 days of exposure at the KSC Beachfront**

**Alodine 1200S**

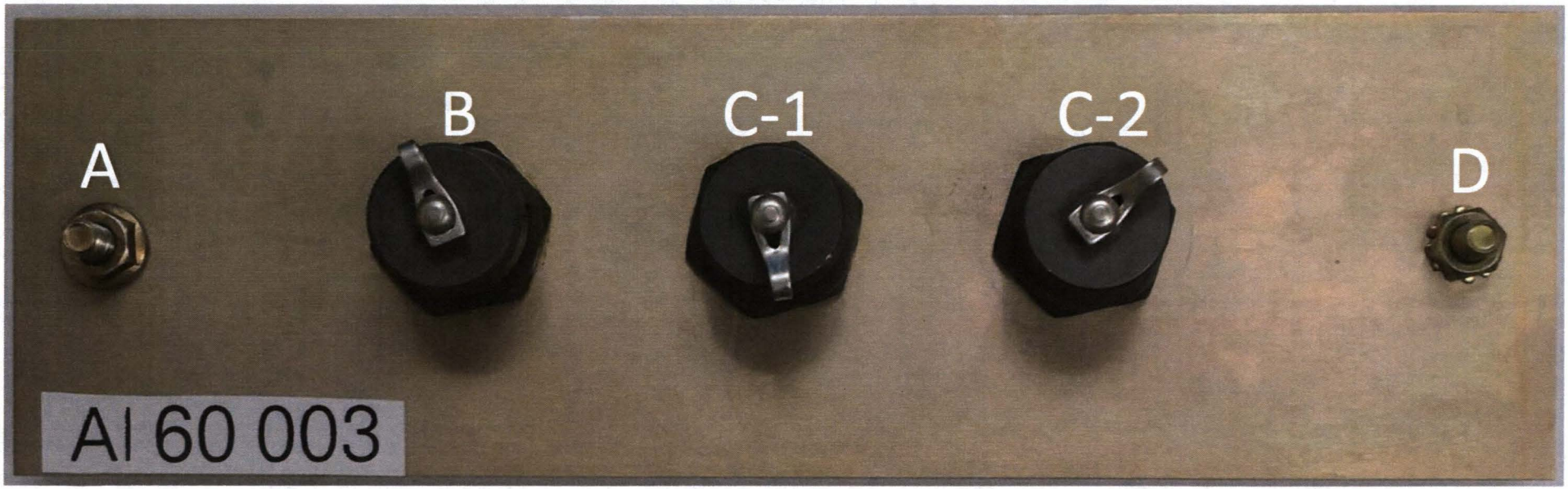
| Ground | Connector | Pass | Fail |
|---|---|---|---|
| Stud A | B | 1 | 1 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 0 | 2 |
| | Hole punched after pretreatment | | |
| Hole drilled prior to pretreatment | CERAN HVA grease used during install | | |
| | C-2 | 1 | 1 |
| | Hole punched after pretreatment | | |
| CERAN HVA grease used during install | No CERAN HVA grease used during install | | |
| Stud D | B | 2 | 0 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 0 | 2 |
| | Hole punched after pretreatment | | |
| Hole punched after pretreatment | CERAN HVA grease used during install | | |
| | C-2 | 1 | 1 |
| | Hole punched after pretreatment | | |
| No CERAN HVA grease used during install | No CERAN HVA grease used during install | | |

# 6061-T6 test panels following 35 days of exposure at the KSC Beachfront



| DC resistance readings from 6061-T6 test panels following 35 days of ambient office storage | | | |
|---|---|---|---|
| Alodine 1200S | | | |
| **Ground** | **Connector** | **Pass** | **Fail** |
| Stud A | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 0 | 1 |
| | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 0 | 1 |
| Hole drilled prior to pretreatment | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 1 | 0 |
| CERAN HVA grease used during install | | | |
| Stud D | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 0 | 1 |
| | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 1 | 0 |
| Hole punched after pretreatment | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 1 | 0 |
| No CERAN HVA grease used during install | | | |



# DC Resistance Measurements
# Metalast TCP HF

| Pretreatment | Panel # | Substrate | Test | | Initial Average | 35 days Average | % Change | Stud to stud* |
|---|---|---|---|---|---|---|---|---|
| Metalas TCP HF | M 50 - 001 | 5052-H32 | Beach | Grounding stud A | 0.3483 | 1.3567 | 289.47% | |
| | | | | Connector B | 0.4413 | 2.2237 | 403.85% | |
| | | | | Connector C-1 | 0.5828 | 49.6600 | 8420.45% | |
| | | | | Connector C-2 | | | | 0.5089 |
| | | | | Grounding stud D | 0.3871 | 1.5457 | 299.30% | |
| | | | | Connector B | 0.3924 | 2.2806 | 481.25% | |
| | | | | Connector C-1 | 0.4289 | 40.5567 | 9355.24% | |
| | | | | Connector C-2 | | | | |
| Metalas TCP HF | M 50 - 002 | 5052-H32 | Beach | Grounding stud A | 0.8284 | 46.5533 | 5519.89% | |
| | | | | Connector B | 0.4500 | 1.8076 | 301.69% | |
| | | | | Connector C-1 | 0.6307 | 27.6097 | 4277.62% | |
| | | | | Connector C-2 | | | | 0.4081 |
| | | | | Grounding stud D | 0.9188 | 44.5733 | 4751.26% | |
| | | | | Connector B | 0.4418 | 1.8459 | 317.85% | |
| | | | | Connector C-1 | 0.4864 | 27.0967 | 5470.48% | |
| | | | | Connector C-2 | | | | |
| Metalas TCP HF | M 50 - 003 | 5052-H32 | Stored | Grounding stud A | 0.5303 | 2.0185 | 280.63% | |
| | | | | Connector B | 0.4301 | 2.0630 | 379.66% | |
| | | | | Connector C-1 | 0.7838 | 2.1023 | 168.23% | |
| | | | | Connector C-2 | | | | 0.4326 |
| | | | | Grounding stud D | 0.5295 | 2.0912 | 294.96% | |
| | | | | Connector B | 0.3803 | 2.0425 | 437.07% | |
| | | | | Connector C-1 | 0.6810 | 2.2561 | 231.30% | |
| | | | | Connector C-2 | | | | |
| Metalas TCP HF | M 60 - 001 | 6061-T6 | Beach | Grounding stud A | 0.7258 | 8.6300 | 1089.09% | |
| | | | | Connector B | 0.4969 | 1.9686 | 296.17% | |
| | | | | Connector C-1 | 0.8747 | 13.9233 | 1491.84% | |
| | | | | Connector C-2 | | | | 0.7406 |
| | | | | Grounding stud D | 0.5585 | 9.6533 | 1628.54% | |
| | | | | Connector B | 0.2441 | 1.6621 | 580.83% | |
| | | | | Connector C-1 | 0.5331 | 13.7833 | 2485.34% | |
| | | | | Connector C-2 | | | | |
| Metalas TCP HF | M 60 - 002 | 6061-T6 | Beach | Grounding stud A | 0.8105 | 21.0327 | 2495.02% | |
| | | | | Connector B | 0.2646 | 0.7690 | 190.68% | |
| | | | | Connector C-1 | 0.4110 | 4.9454 | 1103.36% | |
| | | | | Connector C-2 | | | | 0.4094 |
| | | | | Grounding stud D | 0.8960 | 33.0300 | 3586.52% | |
| | | | | Connector B | 0.2317 | 0.7267 | 213.62% | |
| | | | | Connector C-1 | 0.2927 | 5.0775 | 1634.51% | |
| | | | | Connector C-2 | | | | |
| Metalas TCP HF | M 60 - 003 | 6061-T6 | Stored | Grounding stud A | 0.3150 | 1.5326 | 386.53% | |
| | | | | Connector B | 0.3810 | 0.8360 | 119.42% | |
| | | | | Connector C-1 | 0.4052 | 0.5893 | 45.41% | |
| | | | | Connector C-2 | | | | 0.5180 |
| | | | | Grounding stud D | 0.3094 | 1.4808 | 378.54% | |
| | | | | Connector B | 0.2618 | 0.6718 | 156.65% | |
| | | | | Connector C-1 | 0.2132 | 0.3522 | 65.18% | |
| | | | | Connector C-2 | | | | |

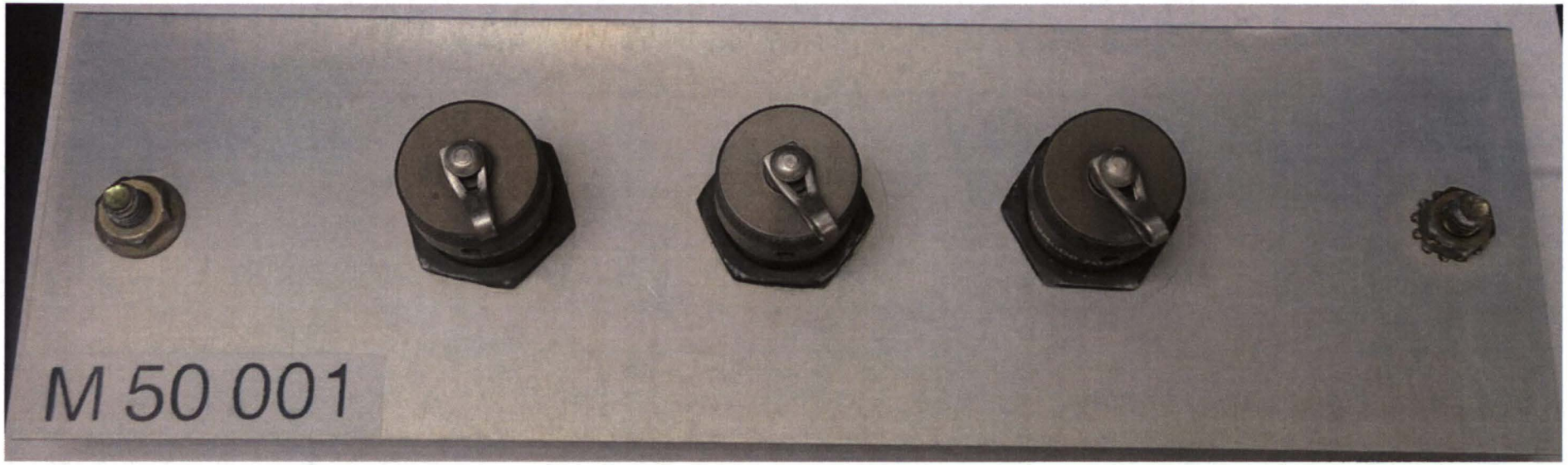
* Stud to stud following 35 days of exposure

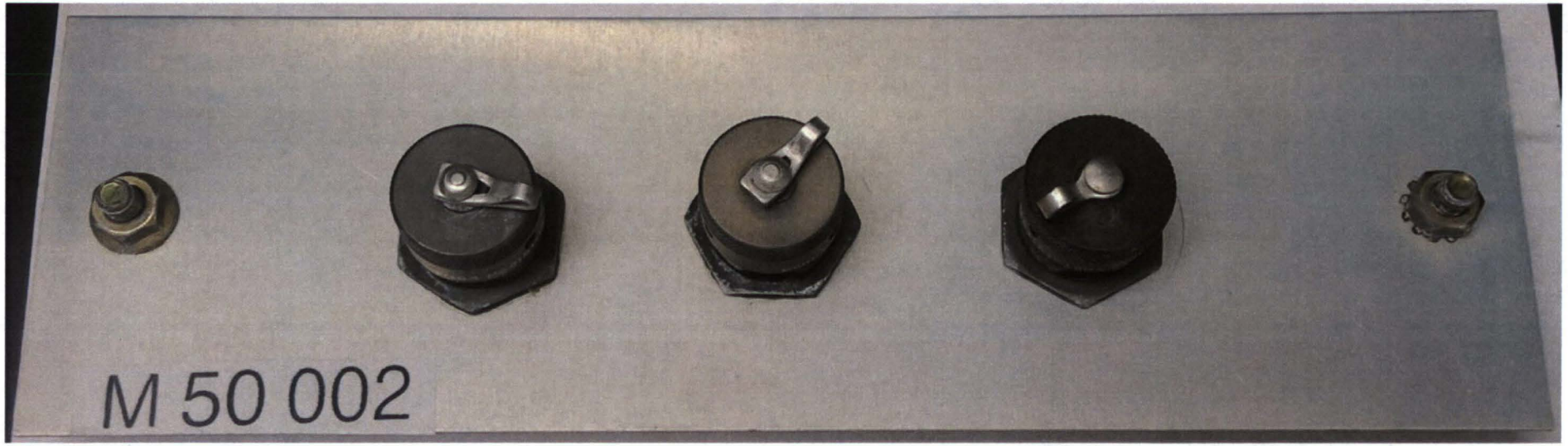
**DC resistance readings from 5052-H32 test panels following 35 days of exposure at the KSC Beachfront**

**Metalast TCP HF**

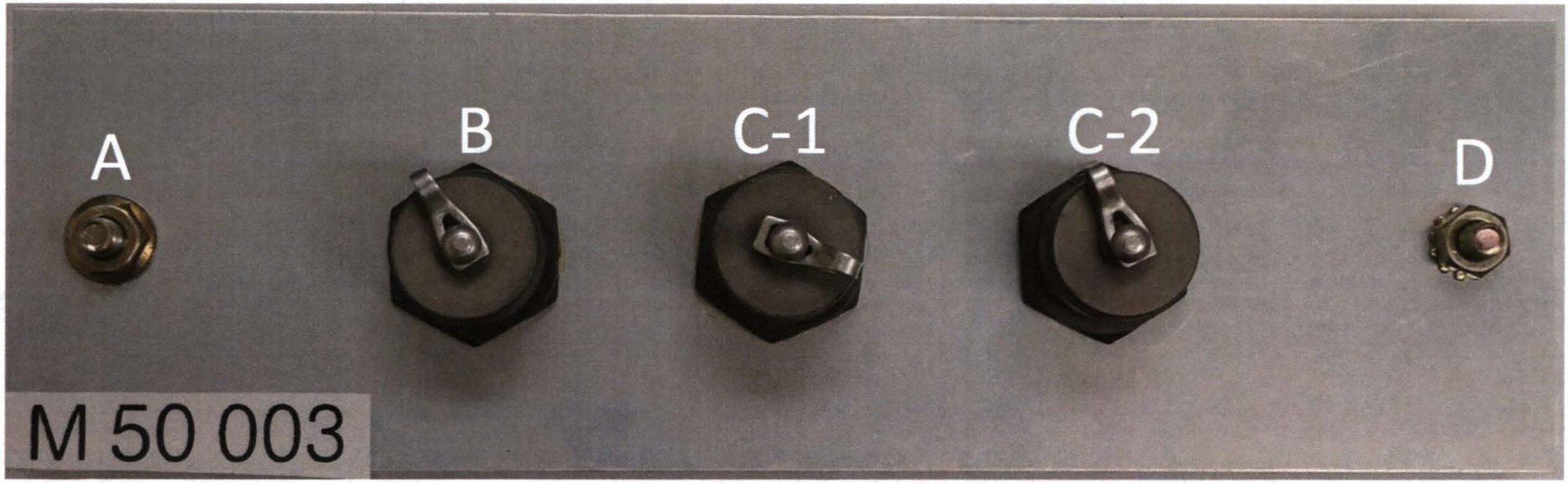
| Ground | Connector | Pass | Fail |
|---|---|---|---|
| Stud A | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 1 | 1 |
| Hole drilled prior to pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 2 | 0 |
| CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 0 | 2 |
| Stud D | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 1 | 1 |
| Hole punched after pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 2 | 0 |
| No CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 0 | 2 |

5052-H32 test panels following 35 days of exposure at the KSC Beachfront



| DC resistance readings from 5052-H32 test panels following 35 days of ambient office storage<br>Metalast TCP HF | | | |
|---|---|---|---|
| **Ground** | **Connector** | **Pass** | **Fail** |
| Stud A | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 1 | 0 |
| Hole drilled prior to pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 1 | 0 |
| CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 1 | 0 |
| Stud D | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 1 | 0 |
| Hole punched after pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 1 | 0 |
| No CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 1 | 0 |

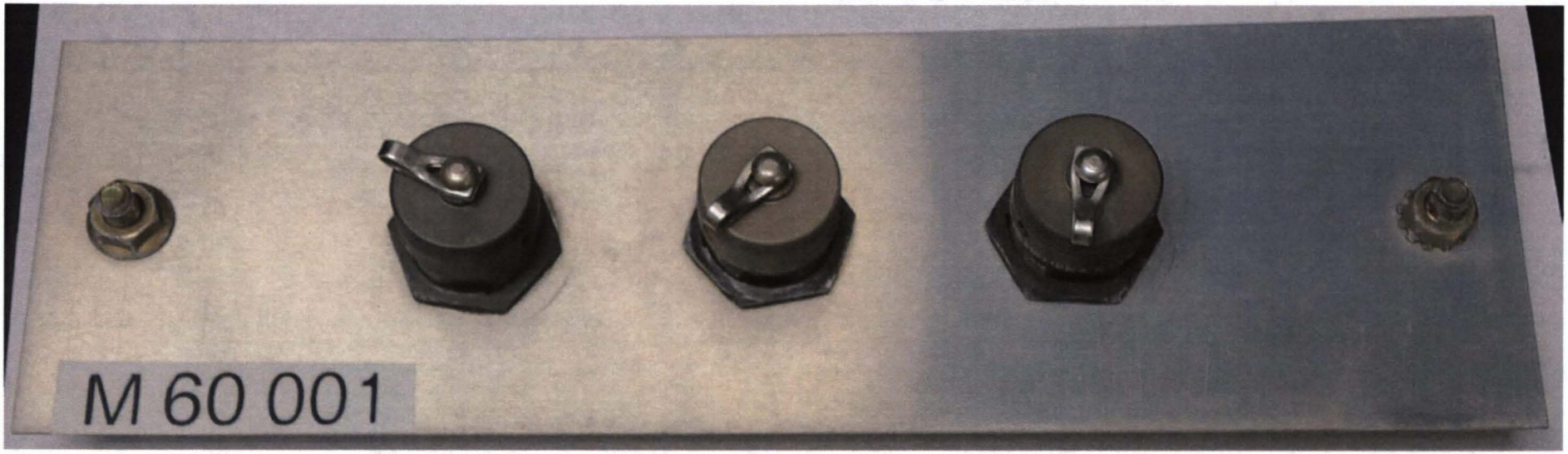


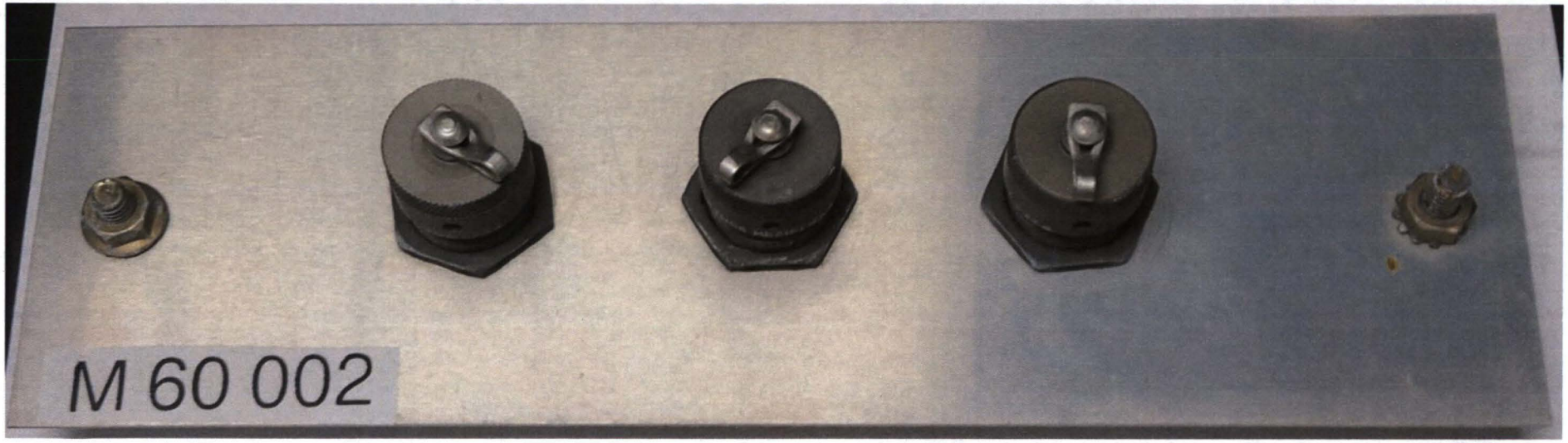
**DC resistance readings from 6061-T6 test panels following 35 days of exposure at the KSC Beachfront**

**Metalast TCP HF**

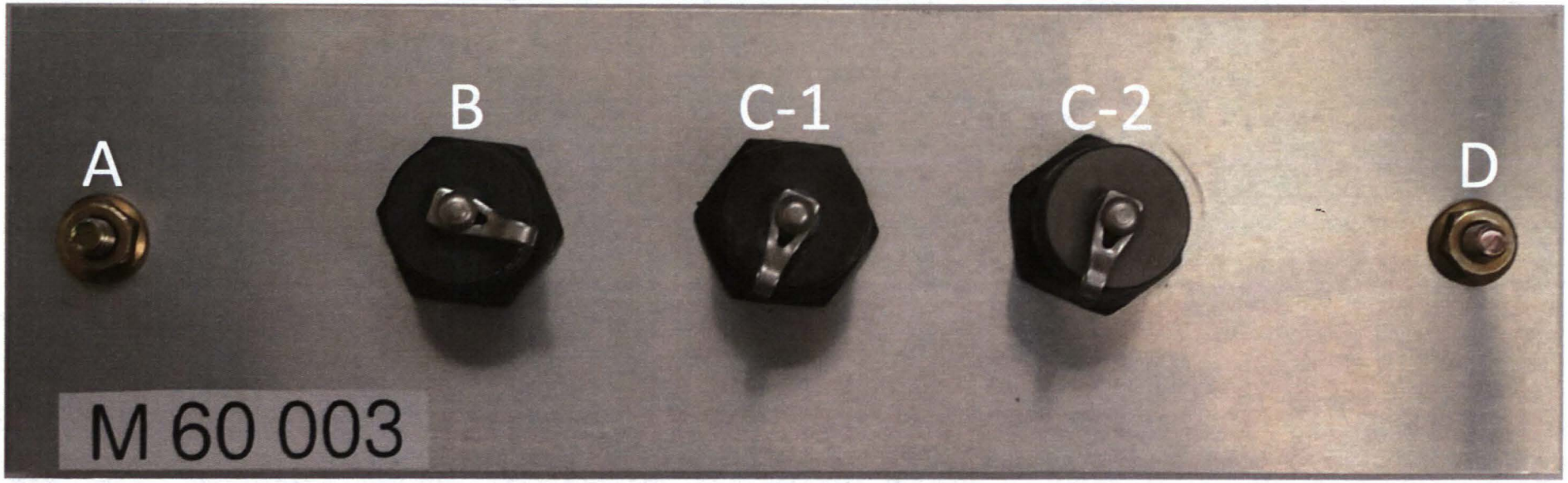
| Ground | Connector | Pass | Fail |
|---|---|---|---|
| Stud A | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 0 | 2 |
| Hole drilled prior to pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 2 | 0 |
| CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 0 | 2 |
| Stud D | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 0 | 2 |
| Hole punched after pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 2 | 0 |
| No CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 0 | 2 |

6061-T6 test panels following 35 days of exposure at the KSC Beachfront



| DC resistance readings from 6061-T6 test panels following 35 days of ambient office storage | | | |
|---|---|---|---|
| Metalast TCP HF | | | |
| **Ground** | **Connector** | **Pass** | **Fail** |
| Stud A | B | 1 | 0 |
| Hole punched prior to pretreatment | Hole punched prior to pretreatment | | |
| CERAN HVA grease used during install | CERAN HVA grease used during install | | |
| Stud A | C-1 | 1 | 0 |
| Hole drilled prior to pretreatment | Hole punched after pretreatment | | |
| CERAN HVA grease used during install | CERAN HVA grease used during install | | |
| Stud A | C-2 | 1 | 0 |
| CERAN HVA grease used during install | Hole punched after pretreatment | | |
| | No CERAN HVA grease used during install | | |
| Stud D | B | 1 | 0 |
| Hole punched after pretreatment | Hole punched prior to pretreatment | | |
| No CERAN HVA grease used during install | CERAN HVA grease used during install | | |
| Stud D | C-1 | 1 | 0 |
| Hole punched after pretreatment | Hole punched after pretreatment | | |
| No CERAN HVA grease used during install | CERAN HVA grease used during install | | |
| Stud D | C-2 | 1 | 0 |
| Hole punched after pretreatment | Hole punched after pretreatment | | |
| No CERAN HVA grease used during install | No CERAN HVA grease used during install | | |



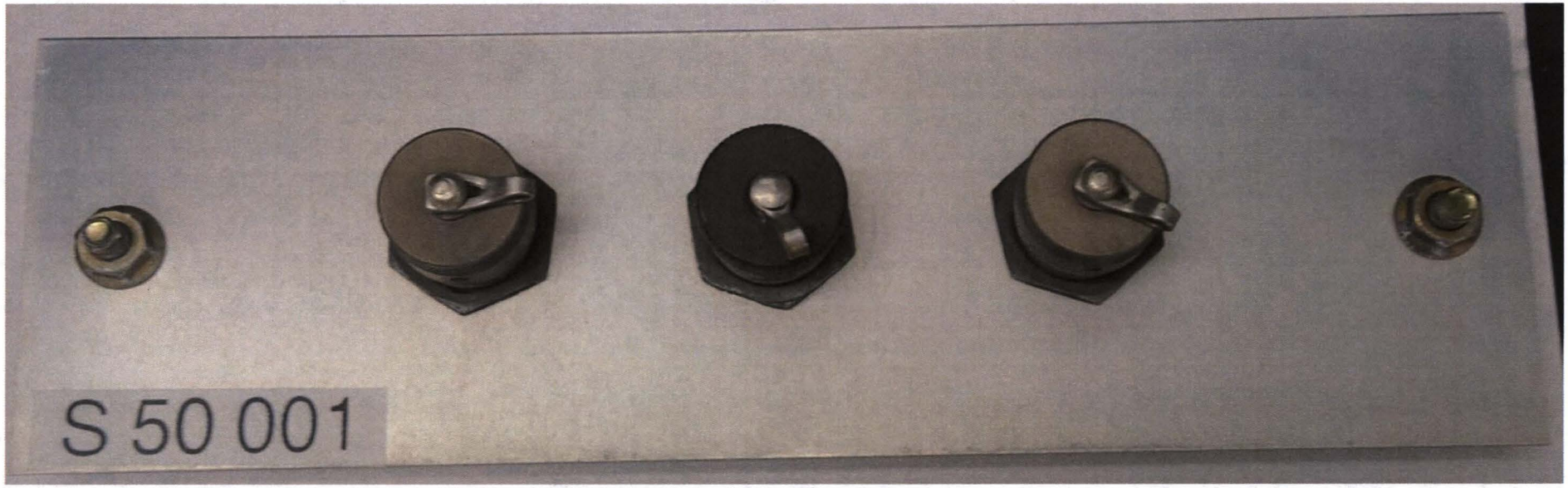
# DC Resistance Measurements
# SurTec 650C

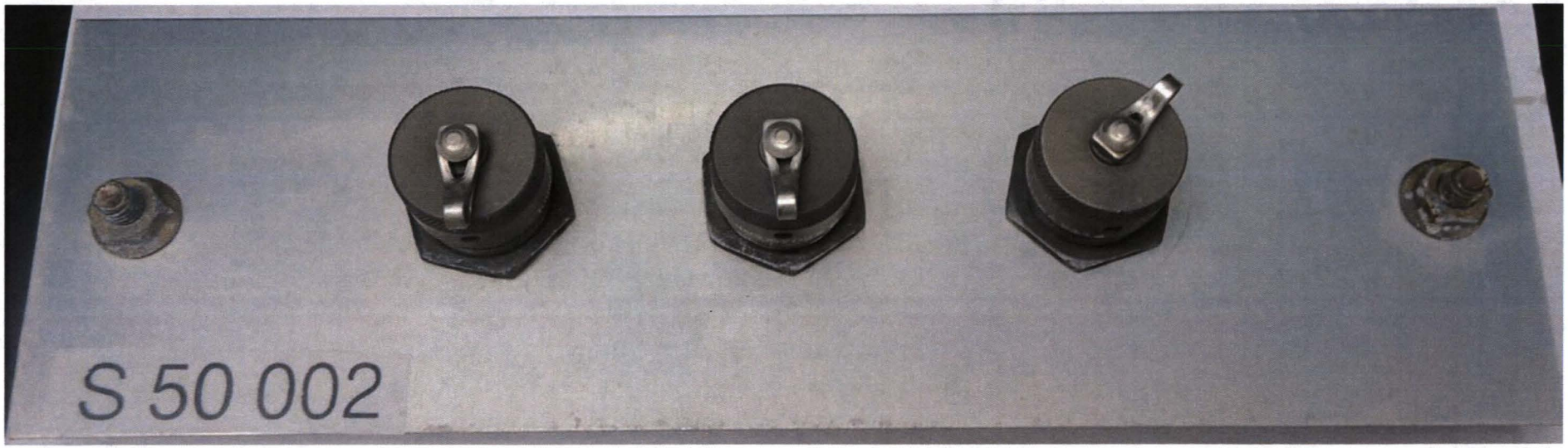
| Pretreatment | Panel # | Substrate | Test | | Initial Average | 35 days Average | % Change | Stud to stud* |
|---|---|---|---|---|---|---|---|---|
| SurTec 650C | S 50 - 001 | 5052-H32 | Beach | Grounding stud A | | | | |
| | | | | Connector B | 0.4008 | 3.9539 | 886.49% | |
| | | | | Connector C-1 | 0.4337 | 0.7630 | 75.93% | |
| | | | | Connector C-2 | 0.5142 | 0.9387 | 82.57% | |
| | | | | Grounding stud D | | | | 0.7689 |
| | | | | Connector B | 0.3753 | 4.5240 | 1105.55% | |
| | | | | Connector C-1 | 0.2773 | 1.0486 | 278.11% | |
| | | | | Connector C-2 | 0.2581 | 1.0895 | 322.07% | |
| SurTec 650C | S 50 - 002 | 5052-H32 | Beach | Grounding stud A | | | | |
| | | | | Connector B | 0.2906 | 2.2122 | 661.15% | |
| | | | | Connector C-1 | 0.2645 | 0.5232 | 97.79% | |
| | | | | Connector C-2 | 0.6140 | 8.0433 | 1209.99% | |
| | | | | Grounding stud D | | | | 0.4685 |
| | | | | Connector B | 0.3810 | 2.2733 | 496.67% | |
| | | | | Connector C-1 | 0.2965 | 0.5540 | 86.81% | |
| | | | | Connector C-2 | 0.5293 | 41.9433 | 7823.80% | |
| SurTec 650C | S 50 - 003 | 5052-H32 | Stored | Grounding stud A | | | | |
| | | | | Connector B | 0.4195 | 1.3230 | 215.36% | |
| | | | | Connector C-1 | 0.3809 | 1.5248 | 300.35% | |
| | | | | Connector C-2 | 0.4412 | 0.7743 | 75.51% | |
| | | | | Grounding stud D | | | | 0.5866 |
| | | | | Connector B | 0.5033 | 1.3935 | 176.87% | |
| | | | | Connector C-1 | 0.3756 | 1.4997 | 299.28% | |
| | | | | Connector C-2 | 0.3081 | 0.6083 | 97.45% | |
| SurTec 650C | S 60 - 001 | 6061-T6 | Beach | Grounding stud A | | | | |
| | | | | Connector B | 0.1827 | 0.3417 | 87.01% | |
| | | | | Connector C-1 | 0.3265 | 1.0405 | 218.64% | |
| | | | | Connector C-2 | 0.3673 | 3.4685 | 844.42% | |
| | | | | Grounding stud D | | | | 0.4697 |
| | | | | Connector B | 0.3079 | 0.4623 | 50.16% | |
| | | | | Connector C-1 | 0.3584 | 1.0674 | 197.81% | |
| | | | | Connector C-2 | 0.3365 | 3.4447 | 923.79% | |
| SurTec 650C | S 60 - 002 | 6061-T6 | Beach | Grounding stud A | | | | |
| | | | | Connector B | 1.6120 | 28.8700 | 1690.94% | |
| | | | | Connector C-1 | 0.3389 | 1.1426 | 237.18% | |
| | | | | Connector C-2 | 0.5253 | 2.5754 | 390.24% | |
| | | | | Grounding stud D | | | | 0.4353 |
| | | | | Connector B | 1.6663 | 20.3100 | 1118.87% | |
| | | | | Connector C-1 | 0.3127 | 1.0948 | 250.14% | |
| | | | | Connector C-2 | 0.4046 | 2.4533 | 506.30% | |
| SurTec 650C | S 60 - 003 | 6061-T6 | Stored | Grounding stud A | | | | |
| | | | | Connector B | 0.3300 | 1.8155 | 450.10% | |
| | | | | Connector C-1 | 0.3711 | 3.7863 | 920.20% | |
| | | | | Connector C-2 | 0.9788 | 10.8320 | 1006.66% | |
| | | | | Grounding stud D | | | | 0.4000 |
| | | | | Connector B | 0.4051 | 1.8937 | 367.47% | |
| | | | | Connector C-1 | 0.3573 | 3.8378 | 974.02% | |
| | | | | Connector C-2 | 0.9348 | 14.4970 | 1450.76% | |

* Stud to stud following 35 days of exposure

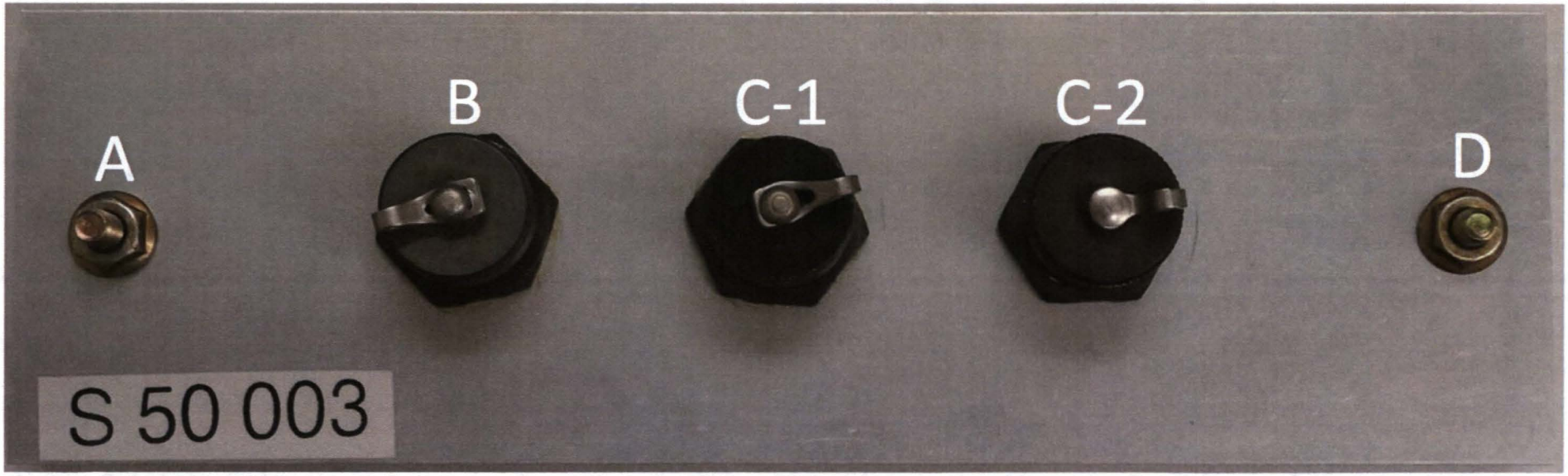
| DC resistance readings from 5052-H32 test panels following 35 days of exposure at the KSC Beachfront | | | |
|---|---|---|---|
| SurTec 650C | | | |
| **Ground** | **Connector** | **Pass** | **Fail** |
| Stud A | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 1 | 1 |
| Hole drilled prior to pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 2 | 0 |
| CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 1 | 1 |
| Stud D | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 1 | 1 |
| Hole punched after pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 2 | 0 |
| No CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 1 | 1 |

# 5052-H32 test panels following 35 days of exposure at the KSC Beachfront



| DC resistance readings from 5052-H32 test panels following 35 days of ambient office storage | | | |
|---|---|---|---|
| SurTec 650C | | | |
| **Ground** | **Connector** | **Pass** | **Fail** |
| Stud A | B | 1 | 0 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 1 | 0 |
| | Hole punched after pretreatment | | |
| Hole drilled prior to pretreatment | CERAN HVA grease used during install | | |
| | C-2 | 1 | 0 |
| CERAN HVA grease used during install | Hole punched after pretreatment | | |
| | No CERAN HVA grease used during install | | |
| Stud D | B | 1 | 0 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 1 | 0 |
| | Hole punched after pretreatment | | |
| Hole punched after pretreatment | CERAN HVA grease used during install | | |
| | C-2 | 1 | 0 |
| No CERAN HVA grease used during install | Hole punched after pretreatment | | |
| | No CERAN HVA grease used during install | | |

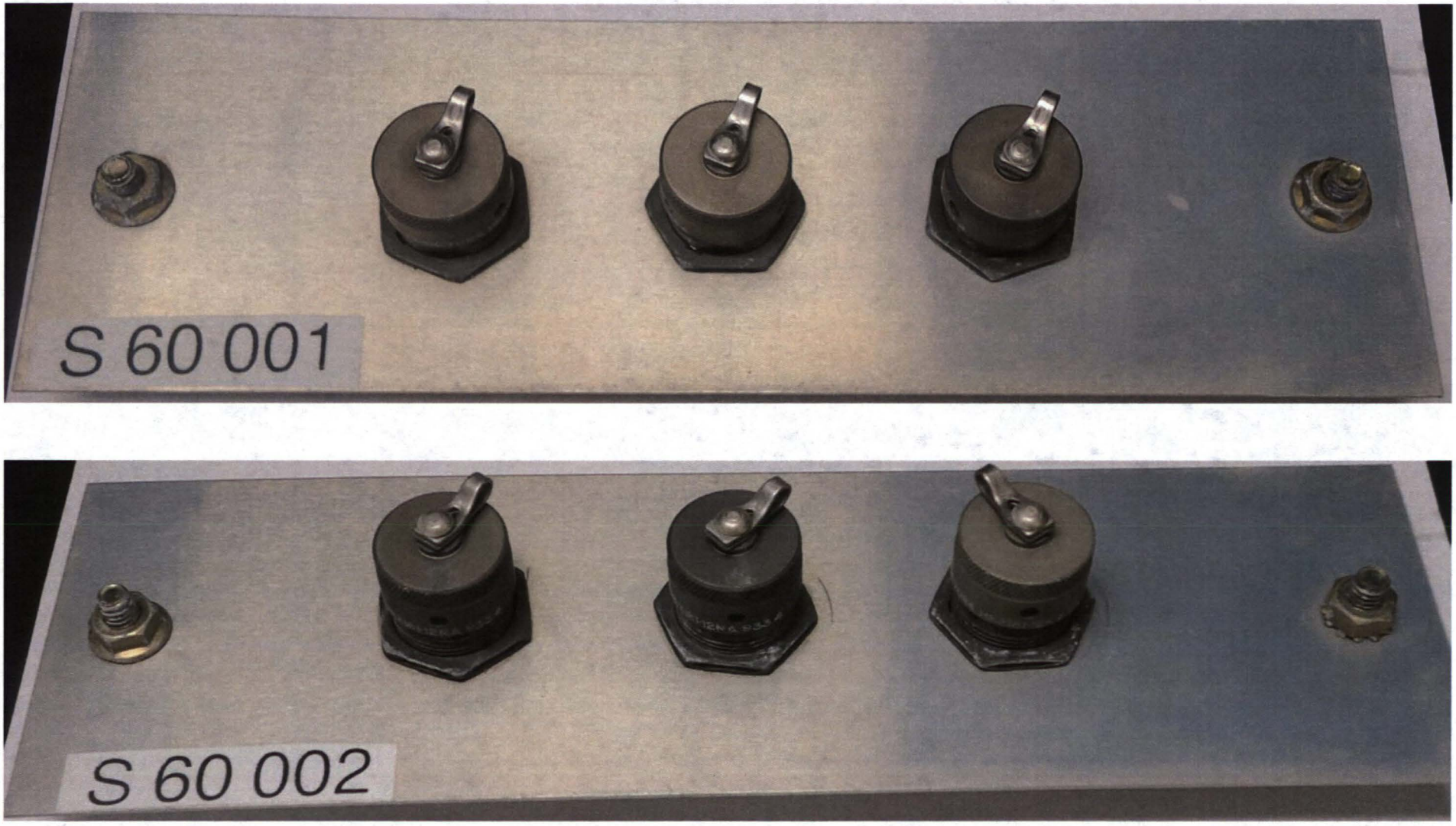


**DC resistance readings from 6061-T6 test panels following 35 days of exposure at the KSC Beachfront**

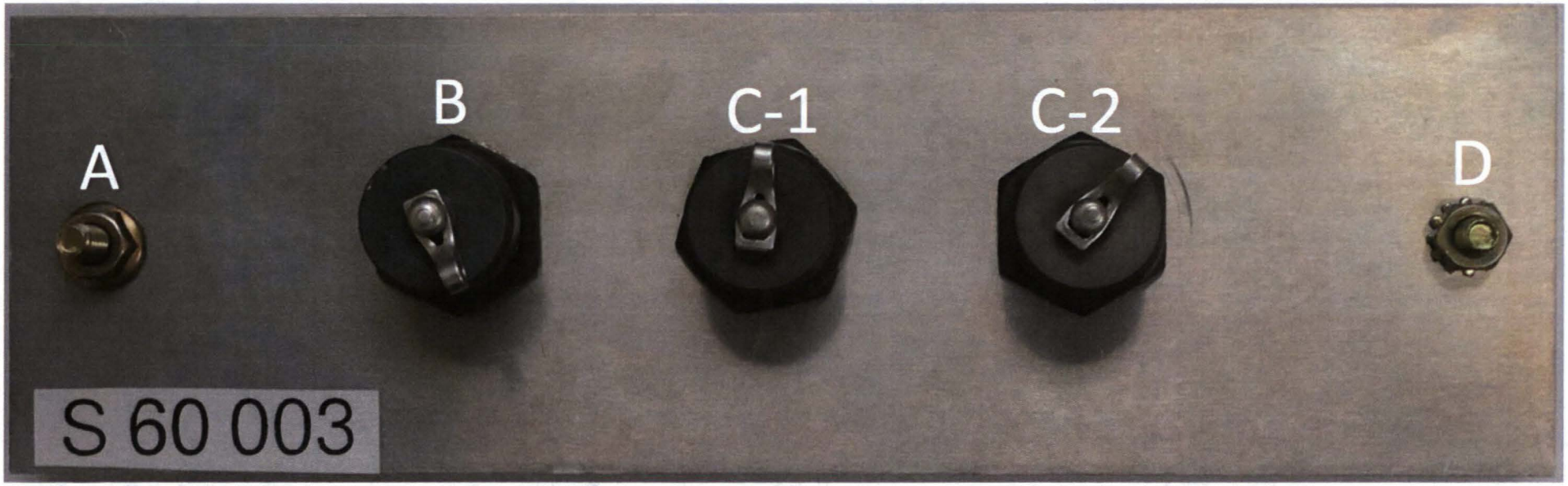
**SurTec 650C**

| Ground | Connector | Pass | Fail |
|---|---|---|---|
| Stud A | B | 1 | 1 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 2 | 0 |
| | Hole punched after pretreatment | | |
| Hole drilled prior to pretreatment | CERAN HVA grease used during install | | |
| | C-2 | 0 | 2 |
| | Hole punched after pretreatment | | |
| CERAN HVA grease used during install | No CERAN HVA grease used during install | | |
| Stud D | B | 1 | 1 |
| | Hole punched prior to pretreatment | | |
| | CERAN HVA grease used during install | | |
| | C-1 | 2 | 0 |
| | Hole punched after pretreatment | | |
| Hole punched after pretreatment | CERAN HVA grease used during install | | |
| | C-2 | 1 | 1 |
| | Hole punched after pretreatment | | |
| No CERAN HVA grease used during install | No CERAN HVA grease used during install | | |

6061-T6 test panels following 35 days of exposure at the KSC Beachfront



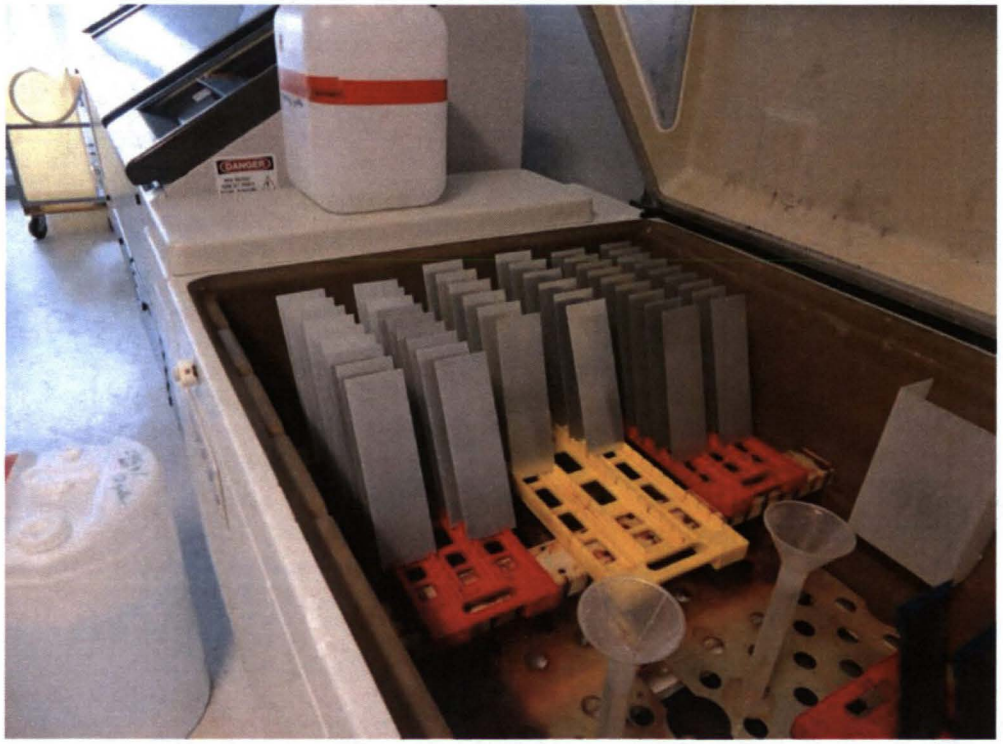
| DC resistance readings from 6061-T6 test panels following 35 days of ambient office storage<br>SurTec 650C | | | |
|---|---|---|---|
| **Ground** | **Connector** | **Pass** | **Fail** |
| Stud A | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 1 | 0 |
| Hole drilled prior to pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 0 | 1 |
| CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 0 | 1 |
| Stud D | B<br>Hole punched prior to pretreatment<br>CERAN HVA grease used during install | 1 | 0 |
| Hole punched after pretreatment | C-1<br>Hole punched after pretreatment<br>CERAN HVA grease used during install | 0 | 1 |
| No CERAN HVA grease used during install | C-2<br>Hole punched after pretreatment<br>No CERAN HVA grease used during install | 0 | 1 |



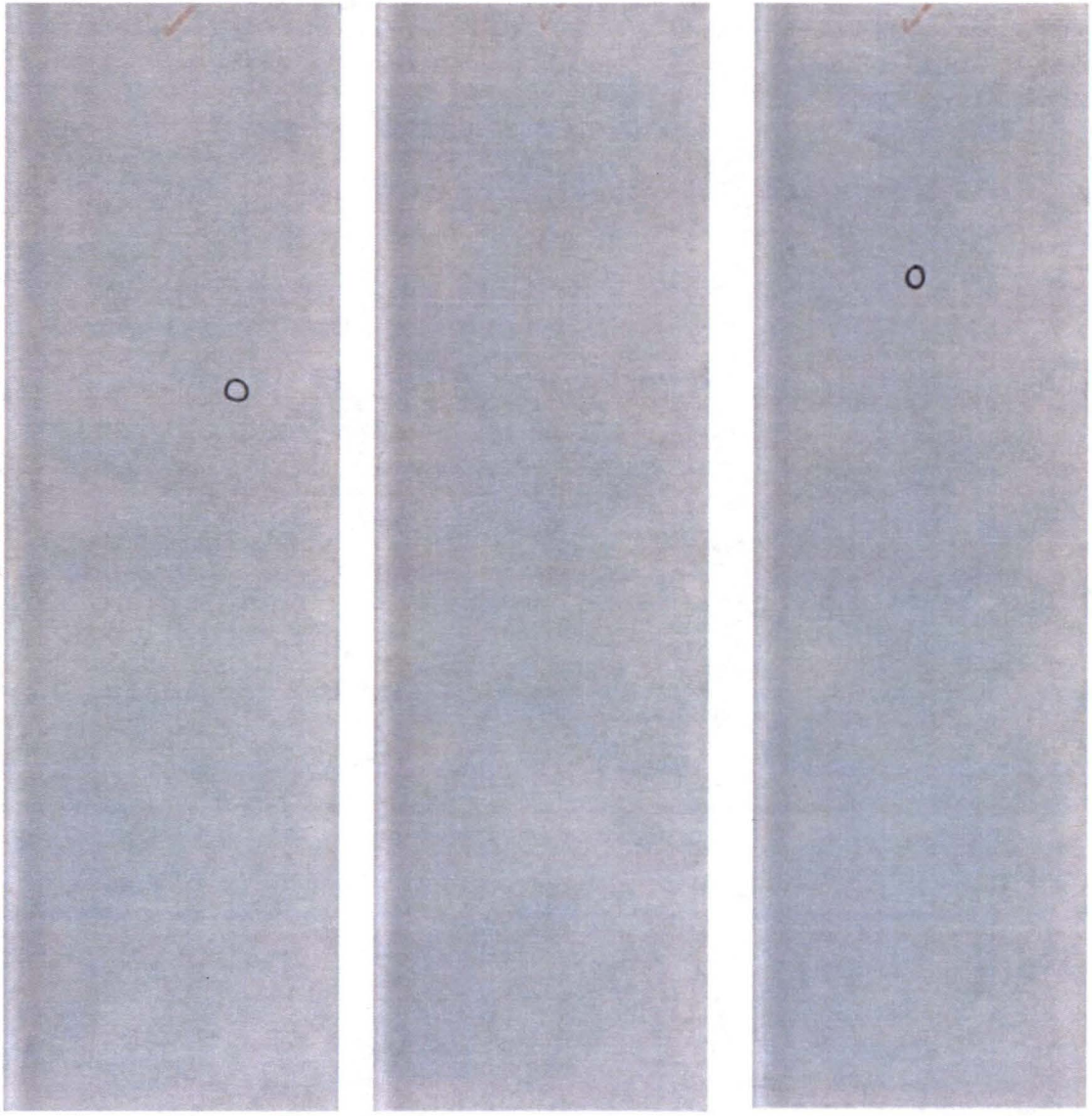
# ASTM B 117 Testing

MIL-DTL-5541F

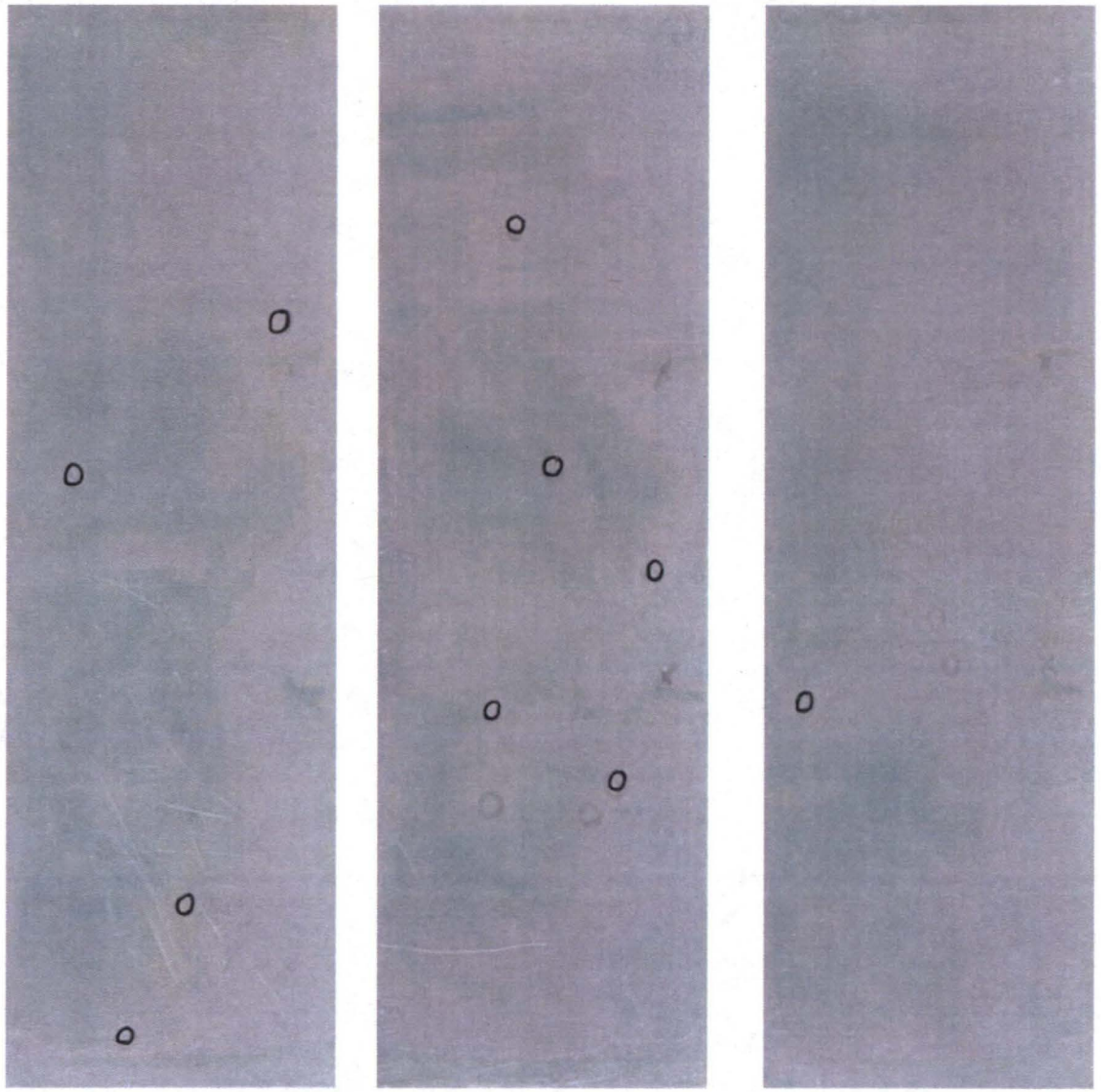
- At the end of 168 hours of exposure to the 5 percent salt spray test; No more than 5 isolated spots or pits, none larger than 0.031 inch in diameter, per test specimen



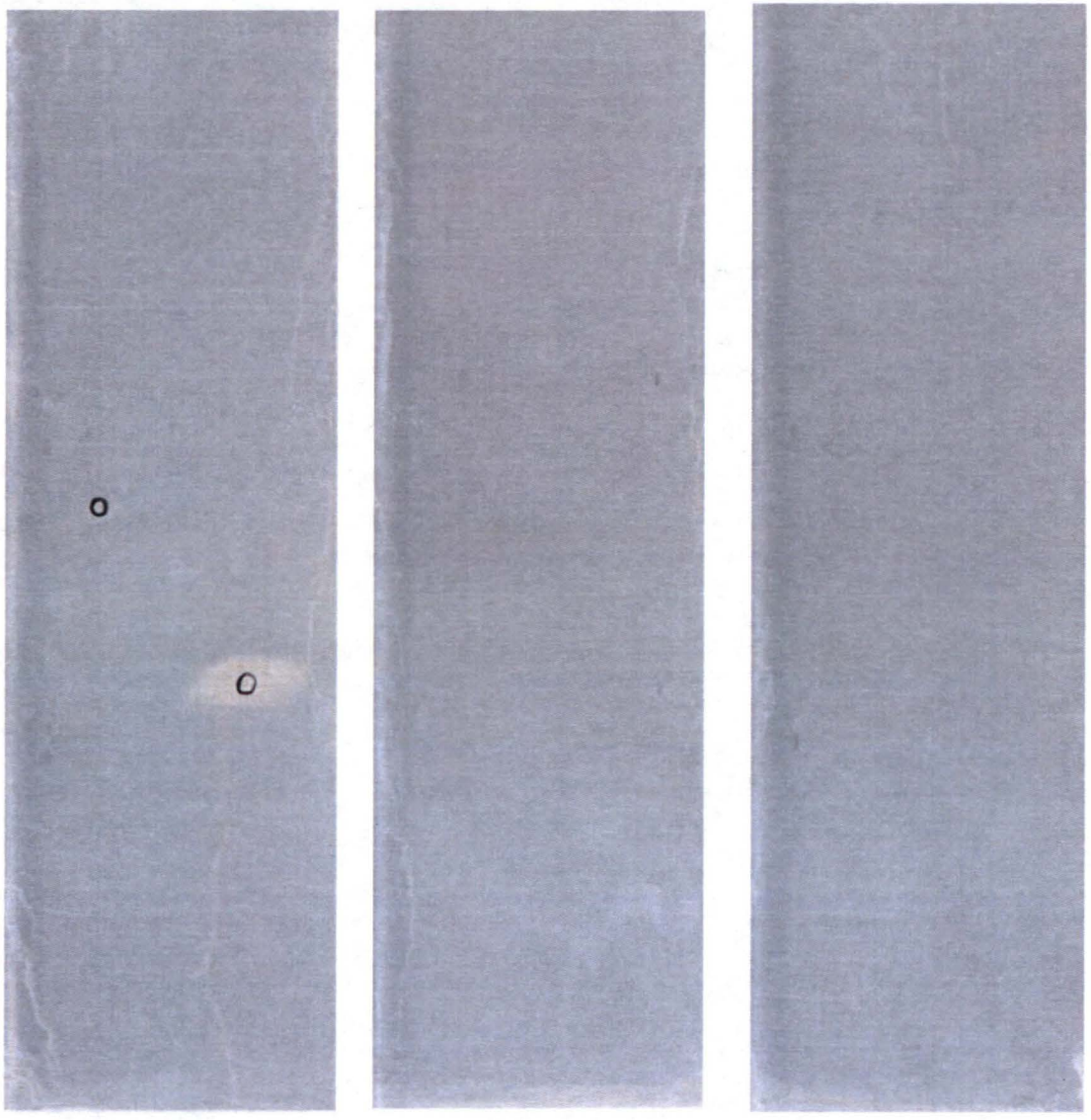
| Pretreatment | Panel # | Substrate | @168 | @336 | @504 | @672 | Total |
|---|---|---|---|---|---|---|---|
| Alodine 1200S | Al 50 - 004 | 5052-H32 | 0 | 0 | 0 | 1 | 1 |
| Alodine 1200S | Al 50 - 005 | 5052-H32 | 0 | 0 | 0 | 0 | 0 |
| Alodine 1200S | Al 50 - 006 | 5052-H32 | 0 | 0 | 0 | 1 | 1 |



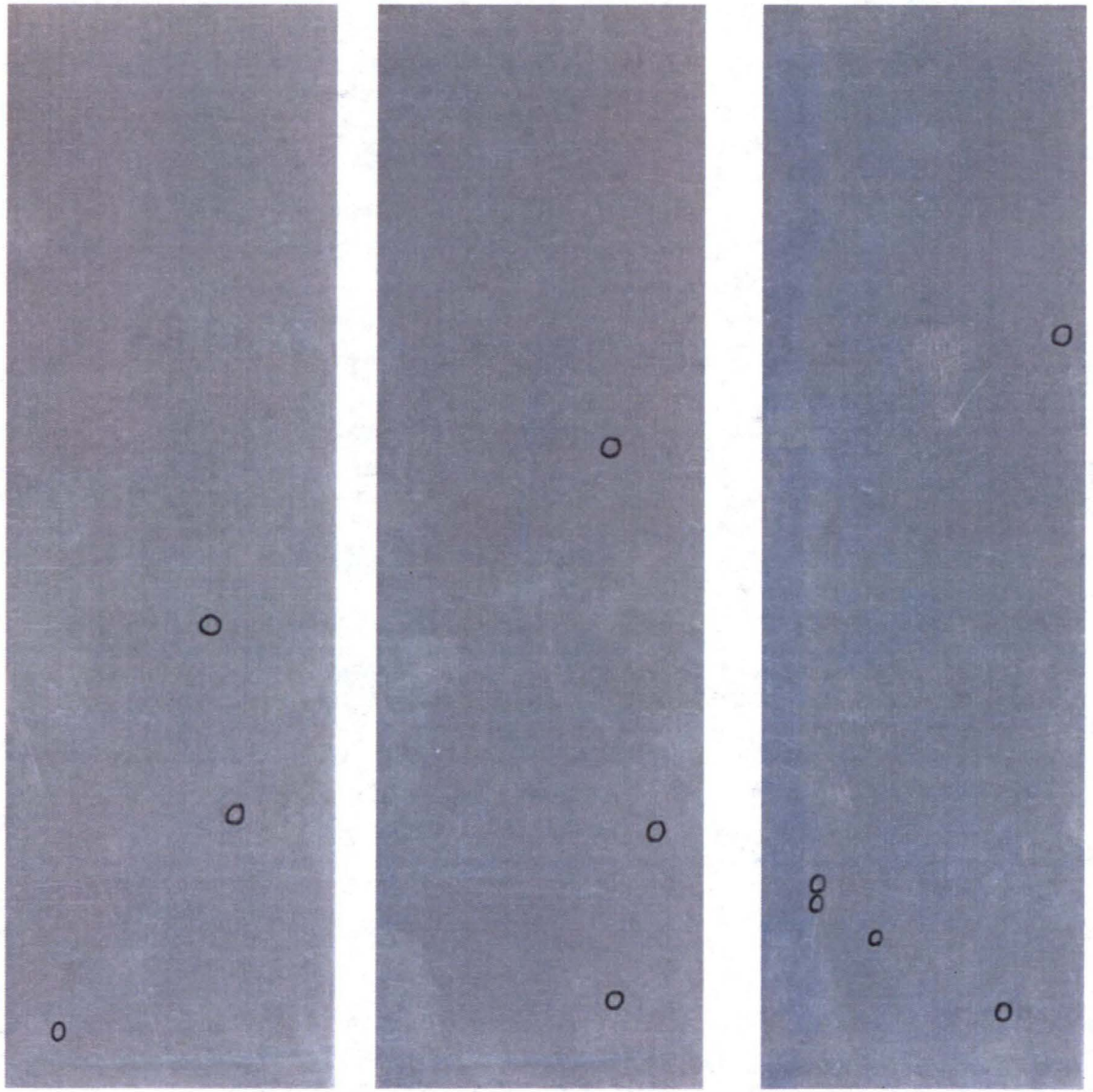
| Pretreatment | Panel # | Substrate | @168 | @336 | @504 | @672 | Total |
|---|---|---|---|---|---|---|---|
| Alodine 1200S | Al 60 - 004 | 6061-T6 | 1 | 3 | 0 | 0 | 4 |
| Alodine 1200S | Al 60 - 005 | 6061-T6 | 2 | 3 | 0 | 0 | 5 |
| Alodine 1200S | Al 60 - 006 | 6061-T6 | 1 | 0 | 0 | 0 | 1 |



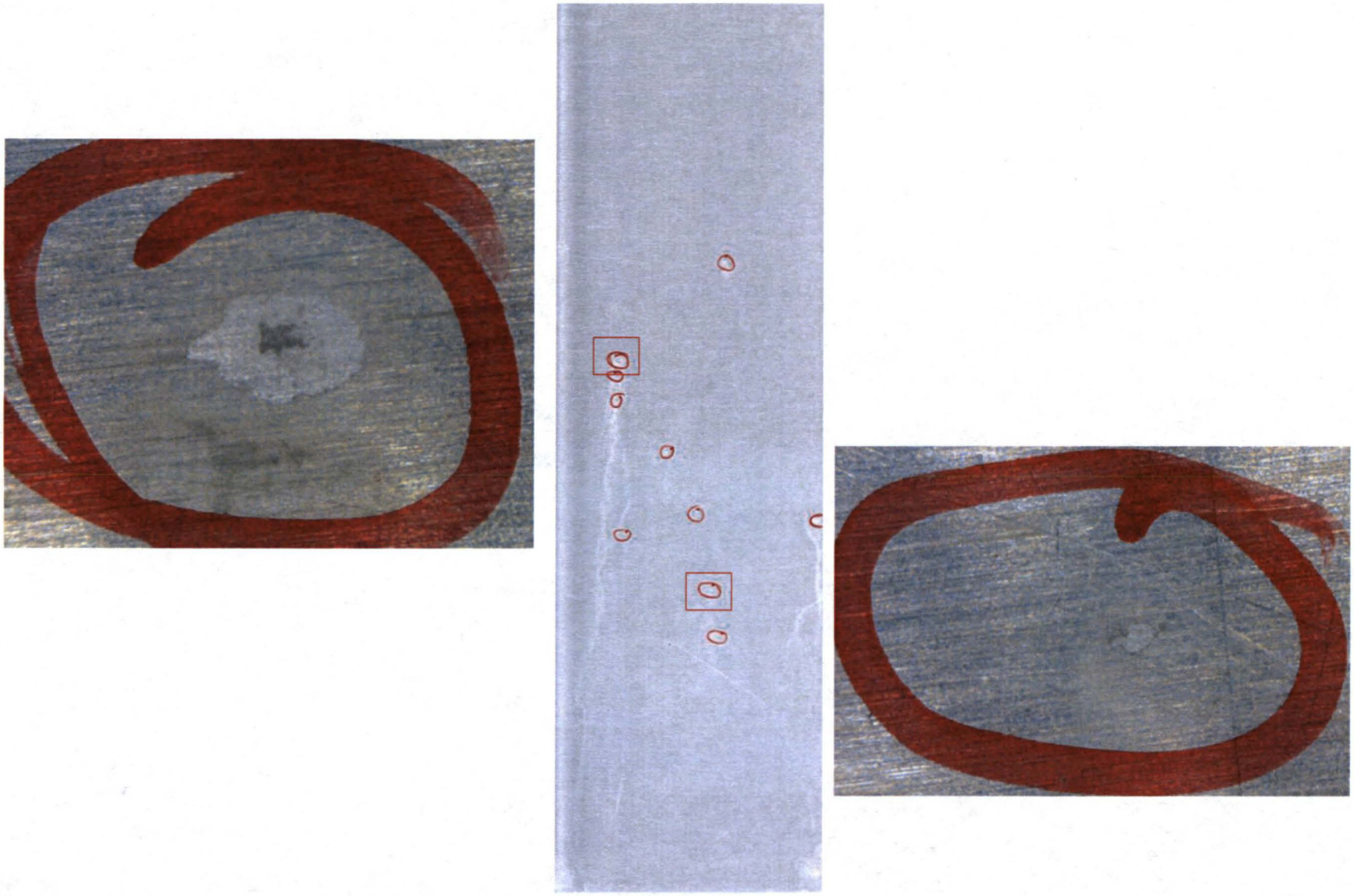
| Pretreatment | Panel # | Substrate | @168 | @336 | @504 | @672 | Total |
|---|---|---|---|---|---|---|---|
| Metalast TCP HF | M 50 - 004 | 5052-H32 | 0 | 0 | 1 | 1 | 2 |
| Metalast TCP HF | M 50 - 005 | 5052-H32 | 0 | 0 | 0 | 0 | 0 |
| Metalast TCP HF | M 50 - 006 | 5052-H32 | 0 | 0 | 0 | 0 | 0 |



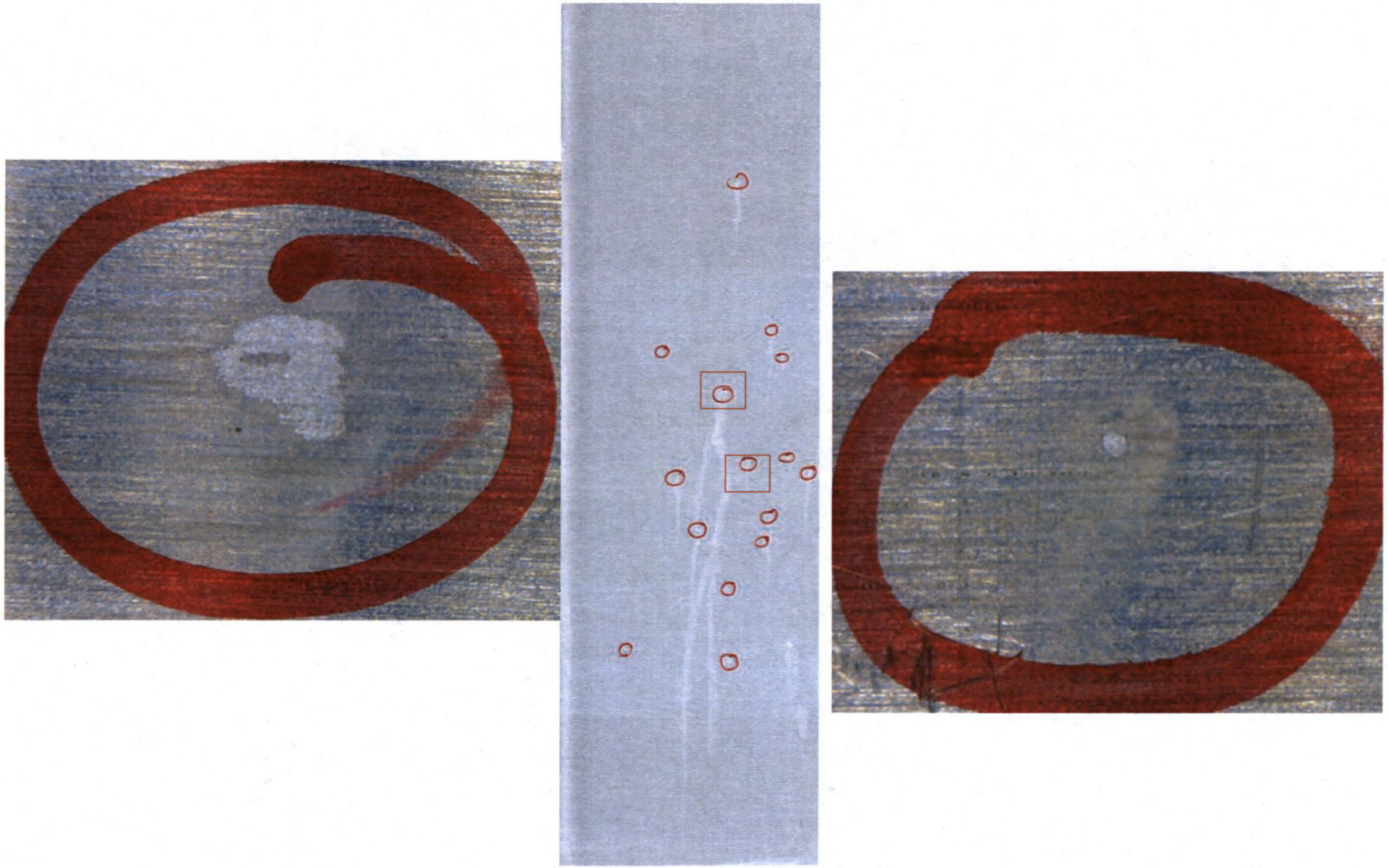
| Pretreatment | Panel # | Substrate | @168 | @336 | @504 | @672 | Total |
|---|---|---|---|---|---|---|---|
| Metalast TCP HF | M 60 - 004 | 6061-T6 | 1 | 1 | 0 | 1 | 3 |
| Metalast TCP HF | M 60 - 005 | 6061-T6 | 2 | 0 | 0 | 1 | 3 |
| Metalast TCP HF | M 60 - 006 | 6061-T6 | 2 | 0 | 3 | 0 | 5 |



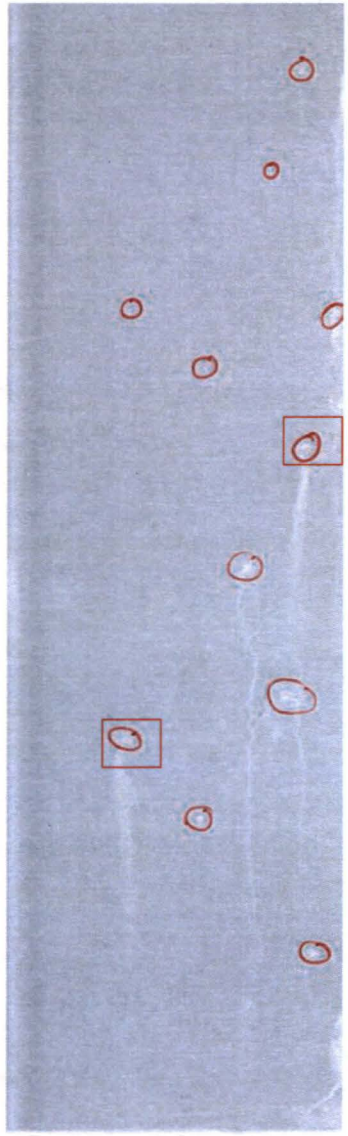
| Pretreatment | Panel # | Substrate | @168 | @336 | Total |
|---|---|---|---|---|---|
| SurTec 650C | S 50 - 004 | 5052-H32 | 0 | 9 | 9 |
| SurTec 650C | S 50 - 005 | 5052-H32 | 0 | 15 | 15 |
| SurTec 650C | S 50 - 006 | 5052-H32 | 0 | 10 | 10 |



| Pretreatment | Panel # | Substrate | @168 | @336 | Total |
|---|---|---|---|---|---|
| SurTec 650C | S 50 - 004 | 5052-H32 | 0 | 9 | 9 |
| SurTec 650C | S 50 - 005 | 5052-H32 | 0 | 15 | 15 |
| SurTec 650C | S 50 - 006 | 5052-H32 | 0 | 10 | 10 |



| Pretreatment | Panel # | Substrate | @168 | @336 | Total |
|---|---|---|---|---|---|
| SurTec 650C | S 50 - 004 | 5052-H32 | 0 | 9 | 9 |
| SurTec 650C | S 50 - 005 | 5052-H32 | 0 | 15 | 15 |
| SurTec 650C | S 50 - 006 | 5052-H32 | 0 | 10 | 10 |



| Pretreatment | Panel # | Substrate | @168 | @336 | @504 | @672 | Total |
|---|---|---|---|---|---|---|---|
| SurTec 650C | S 60 - 004 | 6061-T6 | 0 | 0 | 0 | 2 | 2 |
| SurTec 650C | S 60 - 005 | 6061-T6 | 0 | 0 | 0 | 0 | 0 |
| SurTec 650C | S 60 - 006 | 6061-T6 | 0 | 0 | 0 | 1 | 1 |